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NOTICES.

The Institution as a body is not responsible for the statements or opinions expressed in any of its publications.

Copyright. The entire contents of the Journal are covered by general copyright, and official permission is necessary for reprinting long abstracts; but editors may use not more than three pages of any paper, provided that credit is given as reproduced from the Journal of The Institution of Petroleum Technologists.

Issue of Journal. The Journal appears in four parts per sessional volume, viz. in December, February, April and June. A brochure describing the origin, progress and purposes of the Institution, and comprising also the Memorandum and Articles of Association, the By-Laws and Regulations of the Institution, the Library Catalogue to date (with subject index), and the List of Members, was published in September, 1915, and will be followed annually by revisions of the Library Catalogue and List of Members.

Members of all classes are entitled to receive these publications free: for additional copies of the Journal they will be charged at the price of five shillings per part, and of the brochures at the prices stated on the wrappers, varying in proportion to bulk.

Changes of Address. It is particularly requested that members notify the Secretary immediately of any change of address; and members are also requested to advise the Parcel-Post Department as well as the Letter Office, of any temporary change of address, as, unless this is done, parcel-post packets will not be re-addressed; but will be returned to the offices of the Institution in London, thus incurring further expense for postage.

To Authors of Papers. Papers should be written in the third person, and the copy should be carefully corrected by the author before it is presented.

All drawings, diagrams or other illustrations should be sent in a fit state for direct photographic reproduction.

All quotations, technical terms, and localisms should be indicated by means of inverted commas.

Foreign weights, measures, and costs should be given whenever possible; and also their English equivalents.

It is suggested that authors append as complete a bibliography of the subject treated as may be possible.

All papers and notes submitted to the Institution are supposed to be original communications unless distinctly stated to be otherwise, in which case the exact reference to the previous publication should be given.

Communications upon papers read at meetings, notices of personal movements, or other matter for which publication is desired in the next issue of the Journal, should be in the hands of the Editor on or before the last day of January, March, May or November as the case may be. Subsequent delivery may be too late for insertion.

The Library. In the full catalogue of the Library, published in our brochure of September, were included the titles of such papers in journals received as bear upon any subject within the purview of the Institution. Such titles are not included in the intermediate lists given in our several parts, where, as below, the journals received are acknowledged in single entries.

The attention of such of our members as are authors is directed to the absence of their works from the Library, (with some exceptions), and we shall be particularly thankful for gifts of treatises on special branches of technology, and for separate copies of papers contributed to other Institutions and to journals, either in past or future.

Additions to the Library.

Campbell, M. R. Historical Review of Theories Advanced by American Geologists to Account for the Origin and Accumulation of Oil. *Econ. Geol.*, vol. vi, pp. 363–395. 1911.

Cassier's Engineering Monthly, vol. xlix, pts. 3, 4. 1916.
From Arthur W. Eastlake.

Clapp, F. G. and Others. Petroleum and Natural Gas Resources of Canada. *Canada Dep. Mines, Mines Branch, Rep.* no. 291, vol. ii. 1915.
By Exchange.

Eastlake, A. W. Observations on Petroleum in Eastern Europe, and the Method of Drilling for it. *Trans. Fed. Inst. Min. Eng.*, vol. iii, pp. 693–726, pls. xlix–lii. 1892 (Exc.).
From the author.

Gas and Oil Power, vol. xi, nos. 126, 127. 1916.

HAANEL, E. Summary Report of the Mines Branch of the [Canada] Department of Mines for the Calendar Year ending December 31, 1914. Rep. no. 346. 1915.

INSTITUTE OF MINING AND METALLURGY, BULLETIN, nos. 138, 139. 1916.

INSTITUTION OF MINING ENGINEERS, TRANSACTIONS, vol. l, pt. 4; vol. li, pt. 1. 1916.

KAHNCRETE ENGINEERING, vol. ii, no. 12. 1916.

* MARINE ENGINEER AND NAVAL ARCHITECT, vol. xxxviii, pts. 8, 9. 1916.

By Exchange.

NORTH AMERICA, Geological Map. Pl. 1 of Prof. Papers U.S. Geol. Surv., no. 71. Scale about 70 miles to an inch. 4 sheets.

From W. Sutton.

OIL AGE, vol. xii, nos. 2, 3. 1916.

OIL AND COLOUR TRADES JOURNAL, vol. xlix, nos. 907–915. 1916.

OIL EXCHANGE. Weekly Price List, March 2–April 27, 1916.

By Exchange.

OIL NEWS, nos. 169–178. 1916.

PETROLEUM WORLD, vol. xiii, nos. 3, 4. 1916.

From Sir Boverton Redwood.

RADCLIFFE, L. G., and C. POLYCHRONIS. The Iodine Absorption and Tendency to Sludge Formation of some Hydrocarbon Oils. *Journ. Soc. Chem. Ind.*, vol. xxxv, pp. 340–343. 1916 (Exc.).

From the authors.

ROYAL SOCIETY OF ARTS, JOURNAL, vol. lxiv, nos. 3202–3210. 1916.

SOCIETY OF CHEMICAL INDUSTRY, JOURNAL, vol. xxxv, nos. 4–7. 1916.

By Exchange.

Tracks for Full-Powered Steam Vessels. *U.S. Navy Chart*, no. 1262. Ed. 15. 1914.

United States Oil and Gas Fields in 1913. By D. T. DAY and Others. Two-sheet Map.

From W. Sutton.

As we go to press, we have received consignments of some 50 publications of the United States Geological Survey and the Canada Department of Mines. These will be duly entered in our next issue.

* An addition to our Exchange List, which we do not repeat here.—ED.

Advertisements in the Journal. A limited number of advertisements of firms interested in the Petroleum Industry, may be inserted in the Journal. Application for terms, etc., should be made to the Secretary.

LIST OF ADVERTISERS.

(Members are desired, when making enquiries or placing orders with advertisers, to mention that they have seen their announcement in the Journal).

W. Christie & Grey, Ltd.
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PERSONAL NOTES OF MEMBERS AND SPECIAL NOTICES.

It is suggested that Members of the Institution send information regarding their movements to the Secretary for insertion under this heading.

A large number of the Members availed themselves of the opportunity on April 26th, of congratulating Sir Boverton Redwood on the sustained vigour with which he closed the seventieth year of his strenuous life. All Members will join in wishing a long continuation of his activities.

He has recently been appointed a Member of the Committee of Experts in Mining, set up by the Advisory Council of the Committee of the Privy Council for Scientific and Industrial Research.

Dr. G. T. Beilby is slowly recovering from a recent operation.

Dr. J. A. Leo Henderson left for Canada in March.

Sir Thomas H. Holland has left for India on a Government engagement, which will occupy many months.

Mr. R. Stileman is a First Lieutenant in the 4th Battalion Somerset Light Infantry.

Mr. John Wells has left for Egypt.

Addresses wanted: Messrs. J. T. Armstrong and M. S. di Mendonça.

The Members will learn with great regret of the decease, on April 24th, of Mr. JOSEPH GURNEY FOWLER, the senior partner of Messrs. Price, Waterhouse & Co., our honorary auditors, himself personally supervising our accounts from the commencement of our existence.

Besides his functions as auditor to many of the leading organisations of the Kingdom, railways, insurance and other companies, he was advisory accountant to the Government in respect of the compensation due to railways for the State control necessitated by the War, and also a member of the Board of Referees for the assessment of duty on excess profits.

DINNER AND LUNCH CLUB IN CONNECTION WITH THE INSTITUTION.

The object of this Club is to enable members to dine together before each Meeting, and to lunch together a few days later, so that they may thus have the opportunity of informally discussing various subjects brought to their notice.

Members are entitled to introduce guests, on giving due notice to the Hon. Secretary of the Club.

As each person present pays for his repast, the Club subscription is a nominal one, only intended to defray the cost of printing and postage. It is at present fixed at five shillings per annum. More than thirty members have already joined the Club.

Sir BOVERTON REDWOOD is the Chairman, and Mr. ARTHUR W. EASTLAKE the Vice-Chairman, of the Club.

Mr. Ashley Carter, of Dashwood House, New Broad Street, E.C., kindly acts as Hon. Secretary to the Club.

EDITORIAL.

Bibliography. The constant flow of contributions to the literature of every branch of all subjects greatly enhances the difficulty of keeping in touch with the useful elements of the torrent, whilst ignoring what is valueless or, it may be, directly injurious as misleading.

To attempt discrimination, it would be necessary to analyse every separate book and article, and to indicate the valuable and worthless portions of each, a herculean task even with the most restricted of topics, and wholly beyond the range of possibility with any of general interest. To include only approved matter is to be at once open to the charge of bias. To accept only what the compiler has personally seen, is to confine the use of the list to those who are under the same limited regimen as regards literary pabulum. To reduce the compilation by the exclusion of all or of some foreign languages, or of matter appearing in the less-known journals in such languages, would shut out a wide range of useful work by assuming those tongues unknown, or those publications inaccessible, to all who may consult the list.

Clearly, therefore, the bibliographer must be absolutely uncritical, including chaff, grain and useless matter alike, and that from every possible source, first-hand or indirect, irrespective of nationality, language or other consideration.

In the matter of later editions of works, important modifications of title should alone be notified: otherwise, the dates of consecutive editions are all that is needed, unless space permits the insertion of pagination, &c., in which case expansion, or retention of original bulk, may convey the extent of re-writing, as distinguished from mere reprinting.

To add secondary references, whether of translations or reproductions in the original language, would inordinately swell the already redundant bulk, however advantageous from the point of view of accessibility of the substitute when the original is not to be seen, or is couched in an unfamiliar language.

A still more knotty question is the admission of anonymous matter, and of articles, etc., in ephemeral publications, whether signed, initialled recognisably, or purely anonymous. Matter of high importance has frequently reached the world first in obscure

paragraphs in local publications, and such *incunabula* are of the highest interest to the later student of the history of the subject, often containing details not subsequently rehearsed.

Yet to include such in bibliographic lists would extend them to unusable dimensions. On the other hand, voluminous official reports, of yet greater value, are often equally anonymous on the title-page, though the responsible contributors may be named in the text. For example a recent memoir of the Canada Department of Mines (no. 291, 1914), on the Petroleum and Natural Gas of the Dominion, has signatures to its different chapters of nine members of the staff, but having none on its title-page is, correctly speaking, an anonymous work. (Still, in my function as Librarian, I have entered it as by "Clapp, F. G., and Others," taking the first name in the text.)

The latitude of discrimination, forbidden in the case of entries in general, must be conceded for anonymous works, and in some instances the criterion of bulk may be applied, big reports being entered and small articles being ignored, without losing sight of the possibility of the latter transcending the former in actual value to science or technology. Big battalions of words may carry the day over serried ranks of facts, but the victory is only ephemeral, and Pyrrhic in character.

The paramount difficulty, however, with which the bibliographer is confronted, lies in the immense number of scientific and technical institutions and independent journals, in all countries and using a wide range of languages.

No matter how restricted a subject be selected, the complete collection of all articles, as well as books, referring to it, would involve the labour of a world-wide staff of contributory searchers, expert in the languages, as well as in the subject, and trained in the bibliographic system of entry. In any wide-ranging subject, reference to the original is practically impossible, and entries must perforce be taken at second-hand, whilst many minor contributions, not by any means valueless, escape detection through the inevitably casual process of collection. The resulting errors are not of omission only. Constantly it is found that titles are misquoted, or references imperfectly given, apart from what may be misprinted words or figures. It seems to be supposed by some that a bibliographer is at liberty to abbreviate or extend a title, and that correctness of reference is a virtue of doubtful importance. We have seen articles, quoted from our own pages, attributed to the

"Proceedings of the Institution of Petroleum Technologists," which is not the title we have elected to use for our Journal.

Again, the readers of carelessly-edited works are continually referred to collateral publications, as in the *X. Y. Journ.*, 1914, pt. 7, instead of to the volume and pages of the matter so loosely indicated. For recent issues, still unbound, this reference to the part is easier for the author, but those who may in future years wish to look up the passage cited may have needless trouble in so doing, from the laxity of the reference. The result of want of system is seen when of several articles by the same author, and from the same journal, some have part-references, some pagination, and some neither.

As to altered titles, the "Contents" page sometimes varies from that in the text, the latter of course, being that which the bibliographer should follow. It is, however, always permissible to add, but within brackets, any essential omitted in the original, thus:—Smith, J. [Geological] Notes on Egypt. *Proc.* &c., &c. If space at disposal permits, a few words may suffice to indicate more precisely the tenor of the article, or the portion directly relating to the subject of the bibliography. Where titles in little-known languages are translated, e.g., from Polish, Russ, or Magyar, they should always be in brackets, not being the original titles.

In the common case of journals in consecutive series, with fresh numeration of volumes, the omission of the series-number is a falsification of the entry which cannot be too strongly reprehended.

In respect of the pagination, it is of but small consequence whether that of a book is given as Pp. viii, 162; 4 pls. or Pp. i-viii, 1-162; pls. i-iv. The shorter form is in our view preferable. For the illustrations, we hold that figures in the text, even if of a whole page, should not be noticed, being included in the pagination: only true plates, separately printed from the text, should be noted. Lastly the date, where not taking the place of a volume-number, should be given at the end, beyond the pagination. Illustration of these points may be found in the bibliographies appended to papers in the Journal.

In our appeal to readers, especially in distant regions, for notices of books and articles of local origin, unlikely to reach us otherwise we trust that these hints may fructify in accuracy and fullness of reference.

Twelfth General Meeting.

A Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday evening, 15th February, 1916, Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. (President), occupying the Chair.

The Members of Council present were Prof. John Cadman, Mr. E. H. Cunningham Craig, Mr. Arthur W. Eastlake, Sir Thomas H. Holland, and Mr. T. C. Palmer.

The President, in opening the Meeting, said that the members knew Mr. Hardy Manfield so well that it was not necessary for him (the President) to say anything by way of introduction, and therefore, as the paper was not a short one, and as there were many present at the meeting who would no doubt desire to take part in the discussion, he would at once call upon Mr. Manfield to read his paper.

The following paper was then read :—

Oil Shales, with especial reference to those of the Dorsetshire Kimmeridgian Series.

By W. Hardy Manfield, *Assoc. Member.*

Introductory.—The subject of Oil Shales is such a large one that it is almost impossible to deal fully with all classes. I propose therefore, whilst touching briefly on Oil Shales in general, to confine my remarks chiefly to one class, namely those which occur in the Kimmeridgian measures, which I have for many years considered to be of the utmost importance, and more recently of great national value as a source of home supply of fuel for our Navy, and of motor-spirit. The large amount of both, which these shales in the Kimmeridgian series are capable of giving, would add not only to our security as a nation, but also help to a certain extent to alleviate the difficulty caused by the enormous increase in the use of motor-spirit.

The great area over which the Kimmeridge Shales exist, undoubtedly justifies the opinion that exceedingly large supplies of their products could be obtained. Mr. Churchill and his advisers at the Admiralty clearly recognised the paramount importance of a home supply of oil fuel for our Navy, and of the Kimmeridge Shales as a means of providing a large proportion thereof.

Occurrence.—Oil Shales are very widely distributed throughout the world. The principal deposits are briefly enumerated below.

Australia.—In the Wolgan and Capertee Valleys in New South Wales exists possibly the richest bed hitherto discovered in any country, and there is a large deposit. These shales have been worked since 1865, and the yearly output in 1912 reached 86,000 tons. Across the northern boundary, similar shales are reported on the Queensland flank of the McPherson mountains.

New Zealand.—Shales occur in various places, and according to report a plant has been laid down.

Tasmania.—Extensive deposits are known to exist, and in the neighbourhood of Latrobe there is now a prospect of their being worked. They also occur at Nook Road and at other places.

Canada.—In New Brunswick, the Albert Shale (Carboniferous) deposits, from the thickness of the seams and the richness of the yield both of oil and ammonia, should prove to be one of the best fields yet known. In Saskatchewan, in the Pasquia Hills near the Carrot River, about 50 miles north of the Canadian Northern Railway, oil shales of the Niobrara Cretaceous 150 feet in thickness have been found. A chance sample of these gave seven gallons of crude oil and 22·5 lbs. of sulphate of ammonia to the ton of shale. Oil shales are reported to exist farther west, and have been met with as far north as Cape Bathurst in the Arctic Ocean.

Nova Scotia.—Oil shales are said to have been found on the north side of East Bay, Cape Breton.

Newfoundland.—Shales are known to exist on the West Coast near Deer Lake.

Africa.—In the Transvaal thin seams of shale are found in the Karoo series (Trias), but the results obtained have not hitherto proved of a promising character. Cretaceous Shale is known in Portuguese East Africa.

Brazil.—Deposits of oil shales, also Cretaceous in age, occur in a long coast belt in the north-eastern portion of Brazil.

France.—In the neighbourhood of Autun, and at Buxière les Mines in the province of Allier three-quarters of a million tons a year is being won. These shales, Permo-Carboniferous in age, are not of very high yield, but the heavy import duty on refined oils enables them to be successfully worked, and gives employment to a large number of men. Elsewhere in France, however, occur shales which yield as much as 80 to 90 gallons of oil to the ton.

Germany.—Oil shales of Liassic age occur over a considerable area in Wurtemburg.

Spain.—At Ronda, also northward of Barcelona, and in Castellon, shales of various geological ages exist under favourable conditions and in considerable quantities.

Serbia.—Shales occur at Alexinatz, and furnish a satisfactory yield of oil.

Great Britain, Scotland.—Shales are mined chiefly in Edinburghshire and Linlithgowshire from seams in the Calciferous Sandstone at the base of the Carboniferous rocks. The annual output has now reached the large amount of between three and four million tons, producing about 24 times as many gallons of oil. Although oil shales occur in many places in Scotland they had until recently only been found in paying quantities in part of West Lothian, Midlothian and Fife. It is now considered possible that some shales of Jurassic age, present in the Islands of Raasay and Skye, are worth working.

——, Wales.—Oil shales were formerly worked in the Flintshire coal measures.

——, England.—The principal deposits of oil shale in England occur in the Kimmeridge Clay in Dorsetshire, where successive beds may be seen in the face of the cliffs along some three or four miles of the coast. Commencing about two miles west of St. Albans Head, they extend westward past Kimmeridge, the village from which the formation takes its name, to Gad Cliff, where they dip sharply, and the overlying Portlands, Purbecks, Wealden, and finally the Chalk constitute the coast in turn for some seven miles. Then the Kimmeridge measures with the oil shales appear again at Ringstead Bay, and are met with on the coast two miles farther west near Osmington Mills. Shortly after this, they pass inland, and are found at intervals on the surface or at no great distance below it, as far as Portesham, some ten miles more, and they may extend two miles farther west to beyond Abbotsbury. No work has however been done farther than Portesham to prove this. At Kimmeridge the writer made a section of about 450 feet, took samples, and determined the comparative value of the various seams.

Oil shales are seen also at the north end of the Island of Portland (as it is called, though it is connected with the mainland by the famous Chesil Beach), the Kimmeridge clay forming the substratum of the island. Though very little exposed now, these shales were worked many years ago.

They are also said to have been found at the north-west end of Portland Harbour at the Ferry Bridge, where the West Fleet or Little Sea, as it is locally called, which separates the Chesil Beach

from the mainland, connects with the Harbour. These are not visible now owing to large quantities of sand having gathered at this spot. Dr. Buckland says there was evidence of spontaneous combustion having taken place there, as it did at Ringstead Bay, where through oxidisation of the iron pyrites the shales caught fire in 1826. A landslip had previously occurred, and an unusually high spring tide, with a strong southerly gale, had caused the sea to break over the cliff, and exposed the shales, which ignited and continued to burn for several years. They are reported to have thrown out volumes of dense and suffocating smoke and flames, which at times could be seen some miles away. Cracks spread over the surface, through which the fire was visible, and the edges of which were covered with deposits of sulphur. The country people were much alarmed, regarding it as a volcano, and expecting an eruption to take place. It is curious that in the same year, 1826, bituminous shales were observed to be on fire at Cape Bathurst on the Arctic Ocean. A similar ignition is recorded as having occurred in the Lias in the cliffs at Charmouth near Lyme Regis in 1751 and 1755. More than one hundred and fifty years later, in 1909, the same thing happened somewhat nearer Lyme Regis, when the shales in the Lias were observed burning.

The Kimmeridge measures appear again in the north of Dorsetshire over a considerable area. At Whiting's Farm, near Shaftesbury, a great many years ago, a pit was sunk with a view to the finding of bituminous shales, but was abandoned after a depth of upwards of 100 feet had been attained. The occurrence of bituminous shales having been regarded as evidence of the proximity of real coal, many attempts to find them were made in old times.

The Kimmeridge measures then pass in a north-easterly direction to Norfolk. Trial shafts have been sunk at Sunning Hill near Oxford, and at Faringdon in Berkshire. Near King's Lynn in Norfolk the oil shales can be seen outcropping, and there is evidence of several tons having been taken out. The country here, unlike Dorsetshire, is very flat, and the measures are so overlaid with gravel and boulder clay, that it is difficult to trace the shales without the aid of boreholes. The Kimmeridge clay continues northward through Lincolnshire to the Humber, and covers a very large area, but here too, it is very much overlaid by boulder clay, and can only be seen at intervals. Oil shales I am told can be observed in the neighbourhood of Caistor near the hills. They are also to be found in the cliffs near Filey in Yorkshire, but are almost completely buried by boulder clay and

landslips, and nowhere in England can a view be had of them that can at all compare with the splendid section to be seen on the Dorsetshire coast. In boring for coal at Battle in Sussex oil shales were found when passing through the Kimmeridge measures, and the Kimmeridge clay was proved to be about 1,500 feet thick there.

Heathfield Natural Gas.—Considerable quantities of natural gas, probably coming from the Kimmeridge shales, were met with when boring for water in 1896 at Heathfield Station in Sussex at a depth of 312 feet. The London Brighton and South Coast Railway took advantage of this gas to light their station and continued to use it for this purpose for several years. Many people went to Heathfield to see this, but it was left to some Americans about five or six years later to endeavour to turn it to better account. A company was formed to utilise the gas for lighting, heating, and power purposes. Several boreholes were put down and the reports in the newspapers on the results obtained were most promising. The writer has not heard the reason why this company did not accomplish more than it did, but possibly their boreholes were too close together. For natural gas to be of great commercial value it must extend over a large area, as, if tapped at intervals of less than a quarter to half a mile or even more, there is a great risk of one borehole exhausting another. The fact that a large number of owners would have to be dealt with, and that this source of light and heat is so little known in this country, makes the proposition a difficult one. Some few years ago there was talk of lighting Brighton and Eastbourne with this gas.

Historical.—Oil shale distillation was first begun in France some years earlier than in Scotland, but the French experiment was not known in Scotland, and the industry there originated independently. Although Mr. James Young took out a patent for the low-temperature distillation of coal in 1850, and distilled oil from the rich Torbanehill mineral or Boghead gas coal in West Lothian for about twelve years, it was not until the supply from this source became exhausted that, in 1862, shale was resorted to. The expiration of Young's patent in 1864 led to the rapid expansion of the Scottish Oil industry, but owing to the discovery of oil in Pennsylvania, followed by the yearly increasing quantities of petroleum lamp oil imported into Britain, and the increase of the number of oil-works, the price of the principal product, burning oil, was reduced from 2*s.* 6*d.* to 1*s.* 6*d.* per

gallon, and for some years it ranged from 1*s.* 5*d.* to 1*s.* This was a sad blow to the Scottish industry, and where 51 oil works existed in 1871, only 30 remained two years later. In 1894 the number was reduced to 13 oil companies, and a few years later to only 6. However by improvements in retorting, the adoption of labour-saving appliances, and economical and efficient working, the industry ten years later was again in a flourishing condition, and in spite of all competition has continued so to the present time.

The shales were known at Kimmeridge in very early days. The Kimmeridge "Coal Money," made of this shale, is considered by Sir C. Hoare to have been the production of a colony who inhabited this site, "neither British nor Roman, but before both." These curious discs, which are from $1\frac{1}{4}$ ins. to $2\frac{1}{8}$ ins. in diameter, and from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. in thickness, and turned with great accuracy, are only found in the neighbourhood of Kimmeridge. Various theories have been propounded; some maintained that this so-called coal money was used as counters or coins, others that it had some bearing on religious rites, since it had often been discovered in tombs, others again that it was simply the refuse left from the making of armlets, rings, bracelets and other ornaments.

There is evidence that potteries existed even then in this neighbourhood, and it is argued that the shale was used for fuel at these potteries. In later years this shale was largely quarried for fuel, and is still used in some of the cottages at the present time. Nothing more is heard of these shales until the sixteenth century. Burton Green mentions that the sixth Baron Mountjoy, who died in 1593, discovered that some of the schists at Kimmeridge could be made to yield alum. The manufacture of alum was continued for some years by Sir William Cavell, who also made glass, and evaporated the sea-water for salt, using the shale for fuel. About 1613 he built a small pier in Kimmeridge Bay, which was destroyed by a storm in 1745.

In 1848 a company was formed to work the Kimmeridge shales, which were shipped to Weymouth, and subjected to destructive distillation there, and the oil refined. The products obtained were: naphtha, burning oil, lubricating oil, tar varnish, and a fertilizer. About 10 per cent. of the volatile matter was left in the ash, the ammoniacal liquor and tar were mixed with it, and the mixture was said to possess a high fertilizing power.

The shales at Kimmeridge were therefore worked for the production of oil before any others, with the exception perhaps of those at Autun in France, experiments with which had been

previously made, if the actual production of oil from them on a commercial basis had not commenced.

It was not until 1850 that Young took out his patent for the low-temperature distillation of coal. In actions brought by the owners of Young's patent for infringements, the defendants claimed that these operations at Weymouth had forestalled Young's patent, but Vice-Chancellor Stuart ruled (Aug. 24, 1864) that "the manufacture of offensively-smelling and unmarketable oils from Kimmeridge shales could not be held to be an anticipation of Young's patent."

This company was reconstructed in 1854, and works were erected at Wareham, ten miles from Kimmeridge, as the retorting of the shale at the latter place was still not permitted. Attention was given chiefly to the manufacture of manure. The shale was retorted at a low temperature and sulphuric acid and water, instead of the tar and ammoniacal liquor, were added to the residue. "The shale produced naphtha 7½ gallons, lubricating oil 10 gallons, pitch 1 cwt., and residue 11½ cwt., together with some fine white paraffin wax and gas. Despite the degree of success which this firm achieved," says Burton Green, "it was unfortunately compelled to abandon the property."

A French company next leased the shales, and in 1858 exported 1,149 tons of shale to Australia and other places, and in the following year 1,170 tons. A shaft was sunk proving the shales at depth some half a mile from the outcrop on the coast. The pier was rebuilt and a tramway laid down to it. The importation of petroleum into this country led to the downfall of this company. After this various small companies leased the shales from time to time, and one, which used the residual coke as a sanitary agent met with a certain amount of success, which might have been considerable but for lack of capital. The next company (Messrs. de Grelle & Co.) turned its attention to oil once more, but did not survive long.

Hitherto the chief work had been done at Kimmeridge, although these shales were also known a great many years ago to exist at Ringstead, Sutton, Poyntz and Portland. It was not until 1857 that shale was discovered farther west. In that year my father met with a bed at Portesham, whilst excavating for the foundations for a water wheel. As Portesham was eight miles from the nearest railway station or port, no advantage could be taken of this discovery until a railway was made, and it was nearly thirty years later that this was done.

In 1883 or 1884, when the railway was being made, and the

oil shales were exposed in a cutting, the late Sir George Elliot interested himself in the matter. Your Honorary Secretary, Mr. Arthur Eastlake, and Mr. J. C. Butterfield were sent down, and in conjunction with the author proved the extent of the shales for a considerable distance along the line of strike by trial pits and shallow boreholes. They were found to be dipping north (which is the prevailing direction of dip throughout the region) at an angle of 15°, and very regularly. A shaft was then sunk to prove them to the dip, and whilst this was being done, numerous borings were made, and in all these boreholes the shales were found. When the shales were first struck in the shaft, there was a great inrush of water, which was successfully handled by Mr. Eastlake. Probably it was a large area which had to be drained, as the same pumps which made very little impression on the water for weeks, had only to be worked a few hours daily, when once the inrush of water had been got under. Some hundred tons or more of shale were sent to Scotland to be retorted. The fact that in those days the Scottish shale industry was under a cloud, and the methods of retorting and refining were much more costly than they are now, combined perhaps with the high percentage of sulphur in the oil, prevented a sufficiently remunerative price being obtained to enable the shales to be worked.

In 1890 Sir George Elliot decided to have some further experiments made with the oil. The shaft was pumped out again, and as was the case before, when the striking of the oil-shales caused an inrush of water into the shaft, a large quantity of water had to be lifted before the underground reservoir was emptied, after which, pumping a few hours a day kept the water down. Another hundred tons of shale was raised and sent to Scotland to be retorted. Unfortunately this time the oil was accidentally burnt, and nothing further was done until 1903. Then, it being understood that the sulphur difficulty had been overcome, a quantity of shale was sent to Scotland by the advice of Dr. Boverton Redwood from Kimmeridge, Ringstead and Portesham, and retorted in the presence of Mr. William Sutton and the author. The yield of oil and sulphate of ammonia obtained from each of these samples was most satisfactory. The shales were proved to extend all the way from Ringstead to beyond Portesham. Later it was discovered that the sulphur had not really been removed from the oil, and it was necessary to wait till this could be sufficiently reduced to render the oil saleable in large quantities, before works could be started. A large amount of money has been, and is being, spent to this end. The revised Admiralty Specification

for Oil Fuel in 1912, limiting the proportion of sulphur contained in the oil to 3 per cent. instead of 0·75 per cent. gave encouragement that was much needed.

Geology.—The British oil shales are found chiefly in the Carboniferous and Jurassic systems. In the latter the most important deposits are in the Kimmeridge Clay the lowest division of the Upper Oolites. At Ringstead Bay on the Dorset coast, the Kimmeridge Clay can be traced from the Portland Sands above it to the Coral Rag below. As it approaches the Coral Rag, it becomes more gritty, and fossils belonging to the Coral Rag are found in it. Across the Channel at Boulogne the whole of the Kimmeridge Clay assumes this gritty condition from the Portland Stone to the Coral Rag, and no oil shales are found in it.

The Dorsetshire maps of the Geological Survey show so minutely and accurately the features of this most interesting part of the country from a geological point of view, that it is quite unnecessary to go fully into these. At Kimmeridge itself, with the exception of a number of minor faults which are clearly shown on the map, there is nothing of note. The Coral Rag is not seen here, but a mile or more inland in Smedmore Hill, the Portland Sands above, and the Portland Stone and Purbecks are met with. From Ringstead the Kimmeridge measures extend in a westerly direction to Abbotsbury, where, after passing Portesham, they abut against the Chalk at the Ridgway fault. At Abbotsbury the Kimmeridge Clay is on the south side of the fault and the Greensand on the north side. Approaching Portesham the Kimmeridge Clay is on the south side of the fault and the Chalk on the north side. Farther east again at Sutton Poyntz the Kimmeridge Clay is on the south side and the Greensand on the north side. This large fault, extending from the sea beyond Abbotsbury in an easterly direction for some 16 miles to Chaldon and perhaps a great deal farther, has an important bearing on the shales in this district. At Ringstead besides minor faults there are two important ones. The fault nearest the sea is a downthrow to the south, bringing the Purbecks on a level with the Kimmeridge Clay, and the fault further inland is a downthrow on the north side, bringing the Upper Greensands on a level with the Kimmeridge Clay, causing an upthrow of the Kimmeridge Clay between the two higher formations.

The covering up by the Greensand of the beds between it and the Kimmeridge Clay can be noticed again on going west from Ringstead as Osmington is approached and for a short distance

near Osmington Mills the Kimmeridge Clay is lost to view, the Greensand reaching the Coral Rag. From half-a-mile beyond Osmington Mills the whole of the way to Portesham with the exception that, as mentioned before, for a short distance at Sutton Poyntz it meets the Chalk fault, the Kimmeridge Clay is found resting on the Coral Rag to the south and disappearing under the Portland Sands to the north.

Between Upwey and Weymouth the Forest Marble is elevated, and forms the crest of an anticline on the south side of which the Cornbrash, Oxford Clay, Coral Rag, and Kimmeridge Clay appear in turn, the latter at Wyke Regis. From here it extends southward to the Ferry Bridge, and forms the foundation of the Chesil Beach between this point and Portland and of the anchorage in Portland Roads. It appears again in Portland with the Portland Sands, Portland Stone and Lower Purbecks on top of it. On the north side of the anticline the Cornbrash, Oxford Clay, Coral Rag, Kimmeridge Clay, Portlands and Purbecks, which abut against the Ridgway Chalk fault are all clearly seen. In Norfolk and Lincolnshire the Kimmeridge measures are much overlaid by gravel and boulder clay, and the Portland Sands, Portland Stone and Purbecks are not seen.

Proving of Shales.—The proving of the extent and quality of shales is generally done by boring, although it is very easy to be misled by boreholes, especially if the ground is at all faulty or troubled, and the bores are located at a considerable distance apart. It is quite possible to miss a shale seam entirely, or in the case of a fold-over to find what appears to be a much thicker bed than really exists, or two seams instead of one by going through the same seam twice. Although the sinking of trial shafts is more reliable, this operation is very costly, and takes a long time. If borings have been made sufficiently close together, surprises when the mine is opened will not be very frequent. Boreholes should be put down at intervals along the line of "strike" and at right angles to it on the dip. Boring is not necessary to prove the extent of the Kimmeridge Shales in Dorsetshire along the line of strike, as they can be seen on the coast for several miles, and when going inland outcrop at intervals for a considerable distance. Passing along the Waddon Vale, where they do not come to the surface, they dip so regularly that it has been possible to find them again by means of a shallow trial pit as far as two miles from the last pit put down. Boreholes at intervals however, on the dip, to prove the value of the shales at various depths, would be most interesting; as would a borehole right through the Kimmeridge

measures where they are thickest, to prove whether there are other beds of bituminous shales which might be profitably worked besides the zone exploited. In Dorsetshire the Kimmeridge Clay varies from about 500 feet to 1,000 feet being thickest at Portesham. Authorities, however, differ as to this, the thickness given varying from 300 to 900 feet.

Winning.—Oil shales are worked in the ordinary way by means of vertical shafts sunk through the various beds, or, as is more usual in Scotland, by an inclined road driven in the shale on the dip. Although perhaps not quite as economical in the long run, this method has the advantage that shale is being obtained from the first, and a mine is very soon opened up, whereas in the case of a shaft it is often a long time before any return for the outlay is received. The shales are then usually won by what is known as the "Stoop and Room" method of working, or the "Long Wall." The former is preferable where the seam is clean and 6 or 7 feet in thickness. Levels are driven at right angles to the dip of the shale at regular intervals, and upsets, rising along the bed, are carried from these levels at regular distances apart upwards into the levels above, forming "stoops" or pillars. The width of these is determined by the weight to be borne, the condition of the roof and pavement, and the incline of the seam. When sufficient ground has been opened up by this system, the working out of these pillars, or stooping, is commenced, and carried on systematically. The shale is removed from the stoops, either by taking off a series of slices or "lifts," and supporting the roof by timber (which is nearly all recovered), until the whole is extracted, or by first splitting the stoop up into a number of small pillars, and then removing these, one at a time.

The "Long Wall" method is more suitable when two or more small adjacent seams are separated by waste matter. The whole of the shale in this case is taken out by means of a long working-face, and the waste is used to fill up or partially fill up the space from which the shale has been taken. The roadways are further protected by erections of timber.

This method will probably be found advantageous when dealing with the Dorsetshire Shales, but in some places these are capable of being worked by open-cast methods.

Treatment.—The shales are placed in retorts, and subjected to destructive distillation.

The method employed in retorting shale is most important. The more perfectly this is performed, the larger is the yield both of oil and of ammonia. The quantity and quality of the crude oil

depend largely on the temperature at which it is formed, and to which it is afterwards exposed. Of late years many improvements have been made in this branch of the industry, resulting in a greatly increased yield, and a saving of labour and expense.

The first retorts used were of the horizontal type. The crude oil obtained from Scotch shale by these retorts contained a larger proportion of lighter oil than that produced by the later and more economical vertical retorts, but a smaller quantity of lubricating oil and paraffin scale. Retorts of a vertical type were soon introduced, and later steam was passed into the retorts, which added considerably to the yield of crude oil, and improved its quality. In 1873 a great advance was made when the Henderson retort was brought out. Hitherto the retorts had been fired entirely by coal, but in this system only a small quantity of coal was used. Four iron retorts were built into one furnace, and the spent shale, which contained about 12 per cent. of carbon, was dropped into the furnace to assist the heating of the succeeding charge, whilst the uncondensable gas was also burned in the furnace. There was a great saving in fuel, and the crude oil contained more heavy oil and paraffin scale. The Young and Beilby retort, patented in 1881, introduced further improvements. A large hopper was placed on the top, and the process was made continuous. The lower part of this retort was built of brick, where a higher heat was used, and the gas and ammonia were increased. Auxiliary gas, produced from coal, was used to supplement the retort gas, instead of fresh coal. In 1889 Mr. Henderson brought out a new retort on the Young and Beilby principle, but of much greater length, allowing the shale to be exposed to a larger heating-surface for a longer time. This added several gallons to the yield of crude oil, and much increased that of the ammonia. The charge was supported at the bottom on rollers revolving at a regular rate, which allowed the charge gradually to descend.

The Bryson retort of 1895, which is on the same principle as that of Young and Beilby and latest form of Henderson's and, like the latter, is a very long one, is circular, instead of oval. It has a table below the bottom to support the charge, and a revolving arm which pushes a certain quantity of the charge off the supporting table, and this quantity can be increased or diminished by accelerating or lessening the rate at which the arm is made to revolve. The four retorts in the bench are made to discharge into one hopper, facilitating the removal of the spent shale. As much steam is passed into the highly-heated portion of this retort as will produce the quantity of

ammoniacal liquor that can be most profitably dealt with. It is possible by using a sufficiently high temperature and a large excess of steam, to obtain nearly all the ammonia, but the cost of the steam and fuel and of dealing with a very large quantity of ammoniacal liquor makes the obtaining of the ammonia beyond a certain point unprofitable. These two last retorts were in use a few years ago, and probably are so still.

Until within the last two years the Scotch method of retorting was universally adopted. This method is not suitable to all shales, and successful as the Scottish Shale Industry has been for many years, it is possible that a higher yield of oil of better quality might be obtained from the shales that are now being used in Scotland, and that a large portion of lower-grade shales might be profitably worked if distillation were effected at lower temperatures.

Experiments with Kimmeridge and other shales have shown that retorting at the lowest temperature that will distil the shale improves both the yield and also the quality of the oil, but after the oil has been obtained, the temperature must necessarily be considerably raised in order to get most of the ammonia. The loss of time that would be incurred by distilling at a low temperature in an ordinary retort is overcome by the Tarless Fuel Co., by distilling under a vacuum, and is further lessened by heating the charge from inside as well as outside. This retort (Tozer's Patent) is divided into chambers with hollow ribs all round them, through which heated gas passes.

In the Del Monte low-temperature retort the same idea of heating from the inside as well as from the outside is adopted. The core of the charge is heated by means of a tube passing through it, in which part of the uncondensable gas from the charge is burnt. No vacuum is used. The retort is built at an angle of about 15° from the horizontal, and the charge is fed through it by the old plan of a spiral screw. The retort is heated outside by means of jets, burning the uncondensable gas mixed with compressed air, placed at intervals of about 3 feet. No heat is applied to the lowest third of the retort, where the charge enters. Uncondensable gas is passed in at the top of the retort where the ash is discharged, which drives the vapours down to the cool end, where a large portion of them is condensed by the cold charge coming in, and the oil runs out at this end of the retort. All the heavy and medium oils are collected in this way. The uncondensed vapours are passed through a water-cooled condenser, and the light oil obtained. Apparently no provision is made for

raising the temperature sufficiently high to obtain all the ammonia, but this could no doubt be arranged. It is claimed that "by Del Monte methods the average yield of oil from Kimmeridge Shale is 80 gallons per ton, and the percentage of sulphur is three times lower, being less than the 3 per cent. Admiralty standard. Moreover the sulphur is in such a compound that it can be entirely eliminated." I should be glad to learn that this is the case.

Another low-temperature retort, on an entirely different principle, has been designed, which in the case of the Kimmeridge Shale is said to give a considerably higher yield of oil than any other retort, and oil of better quality.

Products.—The gases and vapours are drawn from the retorts through condensers, in which the heavier oils and the greater part of the steam are condensed, the condensing steam absorbs the ammonia and ammoniacal liquor and crude oil are obtained. The uncondensed vapour is then passed through naphtha towers, and stripped of its naphtha, and after being scrubbed to recover any ammonia left in it, is used to fire the retorts. The crude oil is generally pumped to the refinery, where it is split up into naphtha, burning oil, gas or intermediate oils, lubricating oils, solid paraffin, &c. and the products are afterwards further refined and split up; but in the case of the crude oil from the Dorset Shale, it would perhaps be most advisable simply to pass the oil through a converter, and after obtaining by this means some 20 to 30 per cent. of motor spirit, to use the remainder as fuel oil. The naphtha is split up into motor spirit, lower-grade spirit and solvent naphtha.

The ammonia is driven off from the ammoniacal liquor, caught in sulphuric acid, and formed into sulphate of ammonia, which, as it sells at about £14 per ton, is a most important factor in the shale industry. Shales rich in oil are often poor in ammonia, and *vice versâ*. In Scotland the average yield of sulphate of ammonia obtained from the shales worked is about 45 lbs. per ton: some of the shales richest in oil produce only from 20 to 30 lbs. of sulphate of ammonia to the ton, whereas others poorer in oil give from 60 to 70 lbs. The ammonia therefore enables those shales which, on account of their low yield of oil, would be useless, to be profitably worked. The Kimmeridge shales in Dorset are rich in ammonia. The seam giving the most oil yields 45 lbs. of sulphate of ammonia to the ton of shale, and some of those poorer in oil give a much larger quantity.

Hitherto the ammonia from shales has always been converted into sulphate of ammonia by means of sulphuric acid. This

requires about 19 cwt. of sulphuric acid, costing anything betwen 20*s*. and 40*s*., to make one ton of sulphate of ammonia. The ammonia however, might be taken direct from the vapour by the Burkheiser process, and the cost of the sulphuric acid saved. This process was working successfully a few years ago at some gas works, the only difficulty then being with the converting of the sulphite into sulphate, which was merely a mechanical matter. The inventors contend that the Burkheiser salt, which contains a certain amount of sulphite, is a better fertilizer than ammonium sulphate, and perhaps for this reason did not give sufficient attention to the perfecting of their converter. A farmer however told me that although ammonium sulphate is a most excellent fertilizer, ammonium sulphite has a detrimental action. It is therefore not to be wondered at that there was little sale for the Burkheiser salt, and that it was soon found necessary to convert the whole of the sulphite into sulphate. Perhaps the reason that ammonia from shales is still collected by means of sulphuric acid is, that no new shale works have been built since the process was perfected, and the present companies are doubtless reluctant to scrap their existing plant and incur the expense of erecting new plant, while making so much profit from this product; but I venture to think that if the price of sulphate of ammonia had fallen very much before the war, efforts would have been made to effect this saving. Now perhaps the name of the process sounds too German to find favour, but another name might be substituted.

Sulphur in Shale Oil.—Oil from all shales contains sulphur, but that from most of the shales worked only a very small quantity, less than one per cent. It is the high percentage of sulphur in many shales, or rather the difficulty of removing it, that has hitherto prevented a very large extension of the shale industry. Oil from the best Kimmeridge shales, distilled in the ordinary way, contains from five to eight per cent. of sulphur, and the shales richest in oil have the most sulphur. When Kimmeridge shale is heated in a retort, considerable quantities of hydrocarbons are formed, some of which take up sulphur. There is also a uniting of several hydrocarbon molecules into one by means of the sulphur. These sulphur compounds form at a very low temperature, and when once formed, are very difficult to destroy. When this was ascertained, endeavours were naturally made to remove the sulphur from the shale itself, or to prevent its association with the oil. This can be done, but the process is not commercially available, and up to the present no system which is sufficiently economical and practical, has been demonstrated. Attention was again turned to removing the sulphur

from the oil, or partly from the shale and partly from the oil. Without definite knowledge as to the form in which the sulphur exists in the shale, and in the oil after heat has been applied to the shale, it appears theoretically an easy matter to remove the sulphur, and many chemists have thought they could find a process which would be commercially available, but practically it is very difficult. Some years ago it was thought that the difficulty had been got over, and it was taken for granted that this was so, but when the author investigated the matter he found that the chemist had been entirely mistaken. Since then many chemists, amongst them some of the most eminent, have to my knowledge worked at this problem, and no doubt a number of others have done so, knowing that, not only in England, but in several other countries very large quantities of shale existed, which could be turned to a good use, if the sulphur from the resulting oil could be removed. There was too, the possibility that, if a process involving very slight cost, was discovered which would deal with the sulphur in Kimmeridge shale oil, it might be available for the removal of it from crude petroleum, and so become still more valuable. All ordinary methods failed sufficiently to reduce the sulphur in the oil from Kimmeridge shale. It was found impossible to use drastic treatment, as the sulphur compounds were more stable than the hydrocarbons themselves. The ordinary treatment of agitating with sulphuric acid, and washing with alkaline carbonates, only increased the percentage of sulphur in the oil, as the acid removed a portion of the oil poor in sulphur leaving the sulphur compounds untouched. Submitting the heated oil or its vapour to the action of metals, after treating with reducing agents, was to a certain extent successful, and the offensive odour due to the sulphides was removed. Distilling with alkalis and zinc; distilling through heated calcium carbide; treatment with nascent hydrogen, and precipitation of the separated oil with mercuric chloride, as well as electrolytic methods, all failed to make any appreciable difference.

It was then clearly a matter of research, and more than one claimed to have solved the problem, but on investigation the claims were not borne out. Nevertheless several of them contained excellent ideas, and it is quite possible that the combination of two or more of these processes might have been successful. An interchange of ideas in cases of this kind would be greatly to the benefit of the community at large, but a very difficult matter to bring about. The scientist, who has partially succeeded in unravelling some difficult problem, feels that any day he may achieve

his object, and that by communicating his discovery to others, they may complete his work and reap all the benefit. Thus, what may take years, or may never be accomplished, might by such an interchange be completed in a few months or even weeks.

A number of new methods for desulphurising oil have been invented, but until one is devised which will admit of the desulphurising of Kimmeridge shale oil being carried out on an economical basis, the vast resources represented by these shales for the supply of motor spirit and fuel oil will remain unavailable. Unquestionably, sooner or later the difficulty of desulphurising oil from shales will be satisfactorily overcome, and it is very possible that the Kimmeridge district will at no very distant date occupy a prominent position in the petroleum industry.

In conclusion I wish to thank Mr. Arthur Eastlake and Mr. W. H. Dalton for the help they have given me, and especially the latter for the appended Bibliography.

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DISCUSSION.

The President, in opening the discussion, said his old friend, Mr. Eastlake, reminded him that the present was the first occasion on which a paper had been presented to the Institution by an Associate Member, and he trusted that, having regard to the admirable manner in which the author had dealt with his self-imposed task, many Associate Members and even Students might be encouraged to follow his example. They all might rest assured that the Publication Committee would be most ready to give sympathetic consideration to any communication which might reach them through the Honorary Secretary. The author had performed a service of great value in placing on record the steps which had been taken over a long period in attempts to found a commercial undertaking to develop an industry in the utilisation of the oil-shales of Dorsetshire, to which attention was chiefly directed in the paper. No one was better qualified to undertake that task than the author, because, as the paper indicated, he had been closely associated with the work that had been carried on there. It was quite evident that all that was needed to enable an industry to be founded of the very greatest value as a national asset, providing this country with a source of motor-spirit and oil fuel for the Navy, was to devise a satisfactory method of eliminating the sulphur which occurred in the oil. That element was found in the oil in a form which it was admitted to be exceedingly difficult to deal with. The author had already given some idea of the disappointments which had resulted from unsuccessful efforts on the part of a great many distinguished chemists to deal with that industrial problem, but the reward which awaited anyone who successfully solved the problem was such a tempting one that he could not believe that its solution was likely to be very

long deferred. It was within his own personal knowledge that more than one process had, within the past few months, given exceedingly hopeful results, and he was confident that chemical science would solve the problem, if indeed it had not already done so. The Institution had, in a sense, an *embarras de richesses* that evening, in the presence of several Members of the Council, among them being Sir Thomas Holland, Mr. Cunningham Craig and Prof. Cadman, as well as other members of the Institution, who were not yet Members of the Council, but all specially qualified to take part in the discussion. He found it therefore a little difficult to select one of them to open the discussion, but would ask Mr. Cunningham Craig to do so.

Mr. Cunningham Craig said he had studied oil-shales for some years in different parts of the world, but he had never visited Dorsetshire, and had no personal acquaintance with the Kimmeridge shale. He had learned a great deal from the paper and he wished to learn a great deal more. As the hour was late, he would allude to only one or two points, and then ask a few questions. With regard to the geological structure, it was quite evident from the map that had been shown that the shale outcrops occurred on the flanks of gentle anticlines. He believed those anticlinal structures began in post-Jurassic times, were very much emphasised in post-Cretaceous times, and were finally finished and faulted possibly in post-Tertiary or during Tertiary times. In studying oil-shales in Scotland, South Africa, New Brunswick, Manitoba and Alberta, one very soon found that there were a great many different deposits that could be called oil-shales, because oil was distilled from them. He always understood, though he spoke subject to correction, that the Kimmeridge shale differed essentially from a great many of the deposits that were well-known, and from which oil was extracted in Scotland. For instance, there were shales in Colorado and Utah that really contained crude petroleum, while in Scotland the well-known oil-shale contained what was called kerogen, which was a very useful name, for something which was not petroleum nor bitumen nor resin, but from which petroleum could be distilled. In the cases of bituminous shales or shales containing petroleum, the spontaneous combustion along the outcrops, especially when the dip was very low, was fairly well-known in many parts of the world; it could be seen in Trinidad, in Alberta and in various other places, generally above seams of lignite. It also occurred in the shale seams overlying oil rocks, for instance, in Barbados and in Trinidad, and it was, he thought, quite obvious in those cases that the matter

that was burned was of a bituminous nature. There was one case known, he believed, although it was of rather a doubtful nature, of spontaneous combustion in New South Wales, in what were called the kerosene-shales in that colony. He had heard it stated that the shale at Kimmeridge actually had an odour of petroleum, and the suggestion was made that the matter from which the oil was distilled was bituminous, or of the nature of petroleum, rather than of the nature of the kerogen of the Scottish shale. If so, it was quite easy to understand that a low-temperature process was the best way to extract the oil. He also noticed from the analysis given by the author that there was a very much higher percentage of naphtha obtained in the oil than was the case in the Scottish retorts, which suggested that a bituminous or even petroliferous shale was being dealt with rather than a kerogen-shale. That brought him to the questions he desired to ask, namely,

(1) Could the author state what percentage of the shale was soluble in, say, carbon disulphide ?

(2) Could he give any analysis of the inorganic matter in the shale ?

(3) Were the shales sharply marked out from the surrounding clay beds, or did they pass gradually into them ?

(4) Did the shales decrease in productivity when they were traced along the strike, or down the dip, or in any particular direction ?

(5) Had the author any microscopical sections of the shales, showing in what form the material occurred from which the oil was derived ?

The answers to those questions would greatly help the members to understand the particular condition in which the deposits at present existed, and therefore the best process by which the oil could be extracted in the greatest quantity and of the finest quality.

Sir Thomas H. Holland said the paper did not lend itself well to discussion, because it gave a complete account of the subject, and closed it for the time being. It was like all perfect papers ; it tended to kill discussion ; but one or two points might be added, particularly along the lines that Mr. Cunningham Craig had suggested, because further information on the points he had raised was evidently desirable in order to distinguish between the oil-bearing or oil-yielding shales of Kimmeridge, and the so-called true oil-shales of Scotland. The shale of Scotland was not really a shale from the geological point of view, so that it would be of interest to know whether the real shale character existed

in the Kimmeridge or not. For instance, the specific gravity might be added to the characters that Mr. Cunningham Craig had suggested as among those that were of determinative value. As the author had studied not only the local occurrence of shale at Kimmeridge but of oil-shale generally, he could probably give an answer to that question. Of all the oil-shale occurrences in different parts of the world those from New Brunswick, and the Canadian occurrences generally, and of New South Wales—(he would not say anything about the South African)—were sufficient examples, well-known to everybody present, of oil-shales that yielded far more oil and sulphate of ammonia than the Scottish oil-shales, but why did not they pay? The only satisfactory answer that he had heard to that question was that the Scottish oil-shales occurred in Scotland, and consequently they were worked by Scottish men.

The whole of the controversial questions connected with the paper were really chemical and not geological. The geologist, or at any rate the geological mapper, had done his duty; the shales existed in great quantity and were well distributed and well preserved. It was for the chemist to say how those shales could be utilised,—not to get rid of the sulphur, but to turn the sulphur to account as a by-product; and it would then be found that sulphur, which was now a nuisance preventing the product being utilised at all, might, like ammonia sulphate in connection with the Scottish shale-industry, become one of its principal sources of income.

Prof. Cadman desired to add his tribute of thanks to what had been said regarding the intensely interesting account the author had given of the Kimmeridge shale, and to emphasise Sir Thomas Holland's remarks on the research that was required to put the industry upon a commercial basis. Although no doubt the problem of mining within commercial limits was by no means simple, the dominant difficulty seemed to be largely a chemical question, which had been unsolved for quite a long time; and, as there were some members of the Institution present who had a special knowledge of the chemical side of the subject, he hoped they would express their views on that very important phase of the subject. He congratulated the author on his contribution, which he was sure the members had listened to with the greatest interest.

Dr. J. A. Leo Henderson asked if the author had tested the Kimmeridge shales for free liquid and gaseous petroleum as well as for their bituminous content. Among the instances of

bituminous shales which carry free petroleum and natural gas, that of the Devonian Ohio Shales in Pennsylvania and Ohio, carrying 0·2 per cent. of petroleum and considerable quantities of natural gas, was perhaps best known. In the case of the Ohio Shales no porous media were interbedded, which could serve for the collection and concentration of the oil and gas, which, though present in enormous quantity in the aggregate, were absolutely valueless economically. It would be interesting to know whether the author had any evidence as to the occurrence of sandstones or other porous reservoir rocks carrying oil or gas within the Kimmeridge. Could the author give any information as to the nitrogen content of these shales ?

He thought the addition to the paper of an illustrative detailed geological section, showing the number and thickness of the bituminous bands within the Kimmeridge, would add to its lucidity and fuller appreciation.

Mr. G. P. Ashmore said that in 1893 he worked the Karahuiri petroleum-shale mine in Peru, which was, he believed, the highest mine in the world, being 18,885 ft. above sea level. It was in a Tertiary formation of the Lower Miocene period, but it possessed the structure of a well-defined anticline, and the nearer they approached the apex of the anticline the richer it was in petroleum, while the farther they got towards the syncline the poorer it became. It would be interesting to know whether a similar phenomenon occurred in the Kimmeridge shale.

Mr. Anfilogoff said that in 1906 and 1907 he was connected with a good deal of work that was carried out on the Kimmeridge shales, and, if he remembered rightly, the oil which had to be de-sulphurised had a gravity above that of water. The oil itself contained something like 6 per cent. of water, which it was very difficult to separate, even centrifugally. At that time he thought it would be quite an easy matter to de-sulphurise the oil, because he found traces of all the four sulphur compounds that were known, but, after systematically attacking each of them, he discovered that the oil was richer in sulphur than when he first commenced the experiment. He carried out at the time a number of experiments both on the crude oil and on the distillates, and whether the de-sulphurising process was carried out on the crude oil or on the distillates, the sulphur-compounds present remained as they were before. If he remembered rightly, a small retort was built, not in Scotland, but in Bow, which was worked by a shale-man. He went to see it in order to get some of the shale, and came to the conclusion that it was not a matter for surprise if the experiments

were a failure, because the work was carried out in a rather slovenly fashion, and not at all like that he saw carried out on some of the works in Scotland, where both the retorting and distillation are perfect. Whether that was due to the atmosphere of Bow or not he did not know. In his report, which unfortunately did not go direct to Sir Boverton Redwood, but which he believed eventually gravitated to him, he suggested from his experience that the only way in which the sulphur problem could be dealt with was during the retorting itself. He found that in the laboratory he had reduced the sulphur-content from somewhere about 8 per cent. in the original crude oil, to under 6 per cent., by carrying the vapours over heated metallic oxides. Unfortunately, he had not sufficient leisure to continue the work as a research, but the author or any chemist who was working at the subject was welcome to the results of the work he then carried out, and, if it was of no other useful purpose, it would perhaps save time by warning them what not to do.

Mr. W. J. A. Butterfield thought the paper was by far the most interesting study of Kimmeridge shales that had been written since Mr. Burton Green's memoir on the subject, now rather out of date. He made his acquaintance with Kimmeridge shales about twelve years ago. From the geological standpoint he could say nothing, except that he would like to ask the author if he knew to what extent the Kimmeridge formation extended through the Continent of Europe. He believed he had seen it stated that the immense supplies of natural gas in the neighbourhood of Hamburg were obtained from the underlying Kimmeridge beds, some 15 per cent. of the gas supplied to Hamburg being obtained from that source and mixed with coal-gas. He believed the same deposits extended through Holland, and that a certain amount of natural gas was obtained from them there. If the gas in those cases did come from the Kimmeridge shale, personally he did not regret the reference in the paper to the Heathfield natural gas, though he agreed with Sir Thomas Holland that it was a pity that the principal cause of the failure was not indicated in the paper.

With reference to the Burkheiser process for removing sulphur from gas, it must be remembered that the oil obtained from the Kimmeridge shale contained much more sulphur than was necessary for neutralising the ammonia and converting it to sulphate. It ought not therefore to be necessary to introduce sulphuric acid from an extraneous source. He doubted whether the Burkheiser process was applicable to shale-oil, unless, in the retorting, some

means were adopted for converting the sulphur contained in the oil into sulphuretted hydrogen, and so far as he was acquainted with the gases given off in the retort, the sulphur-compounds were not mainly in the form of sulphuretted hydrogen. Some conversion had to take place before the Burkheiser process could be applied to oil vapours of that kind.

The author had also referred to the possibly larger yield of oil obtainable by the low-temperature distillation of the shale, and had gone on to say that, so far as he knew, no one had afterwards increased the temperature in the retort in order to obtain the maximum yield of ammonia. He thought technically, it would be wrong to attempt to do the two things in one retort. If it was clear that a higher yield of oil was obtained at a low temperature, it would certainly be a mistake to leave the material in the retort, and then to increase the temperature to whatever degree was necessary to get the larger yield of ammonia. Obviously, if a different temperature was necessary, the stuff should be discharged from the low-temperature retort directly into a second retort heated to the higher temperature that was necessary for ammonia production. In that way continuous working and control of the temperature in each retort would be obtained. Until the point was brought to his notice by the author's paper, he had not realised that the best yield in each case could be obtained at different temperatures. The whole problem of the utilisation of the Kimmeridge shale had got on to a different footing of late years, owing to oil now being useful which formerly would have been entirely condemned on account of its large sulphur-content. For fuel purposes the sulphur-content was not so important as in kerosene, and that was shown by the large increase the Admiralty had allowed in the proportion of sulphur in fuel-oil. But even so the oil from the Kimmeridge shale was still considerably above the Admiralty maximum. The problem was a most fascinating one, and he thought it was commercially worth anyone's while to continue his efforts to remove the sulphur from the shale or from the crude oil produced from it. New methods had quite recently been introduced for the removal of certain sulphur compounds from other gases. There was a reference in the paper to treatment with nascent hydrogen and precipitation of the separated oil with mercuric chloride. He would be much interested if the author could state whether the nascent hydrogen had been used in connection with any catalytic agent or not, because experience in other industries suggested that a good outcome might be expected if the hydrogen were used with a catalyst.

Dr. Dunstan pointed out, in reference to the last speaker's remarks, that the South Metropolitan Gas Company had satisfactorily dealt with the carbon disulphide problem in gas by using conjointly nickel and hydrogen, and it seemed to him quite a reasonable line of attack in the present instance. **Mr. Butterfield** said that that was what he referred to in his remarks.

Mr. W. Hardy Manfield, after thanking the members for the kind way in which they had received his paper, said, in reply to Mr. Cunningham Craig's questions, that the shales of the Kimmeridge formation were distinct from the clay, in that the clay was affected by the air. On exposure to air and to weather, the clay crumbled, whereas the shales weathered very slightly, and remained firm and hard. That was one characteristic of the Kimmeridge measures. With regard to the value deteriorating or increasing in various parts, personally he had found that very little difference existed. There might be a difference of just a few gallons in the yield from what appeared to be the same bed. At the same time the bed might not really be exactly the same, and that might account for a varying yield; but assuming, as was probably the case, that the beds found at places 5, 6, 10 or 20 miles apart were the same, the yield was very slightly different. The same remark applied with regard to the depth. All the shales varied slightly; but as a rule the yield was very regular, although naturally different beds varied considerably in yield. Personally, he was not acquainted with any microscopical work done upon the Dorsetshire Kimmeridge shales. In reply to Dr. Henderson's question, as far as he knew there were no oil-shales in the gritty beds of the Kimmeridge clay.

With regard to the Burkheiser process, it was true that the sulphur had to be in the form of sulphuretted hydrogen, but the question that occurred to him was whether it was not cheaper to add sulphur directly to the ammoniacal gas than to use sulphuric acid. In the case of the Kimmeridge shales there would be quite sufficient sulphur for working the Burkheiser process.

No catalytic agent was used at the time in the experiments with nascent hydrogen. He was aware of the fact that a process of that nature had been invented and patented, but whether it was a practical process or not he could not say; he hoped, however, it would be successful on the Kimmeridge shales.

On the motion of **The President,** a hearty vote of thanks was accorded to Mr. Hardy Manfield for his interesting paper, and the meeting terminated.

Mr. J. Wells subsequently wrote as follows:—

Our geological friends at the meeting had asked so many questions that I was unwilling to add to the number. At the same time it was of interest to note that the consensus of opinions expressed raised but one difficulty, that of the sulphur. Admittedly the de-sulphurising of these oils presents very considerable difficulty more especially in regard to what we might term the "ultimate" sulphur, but from the point of view of fuel I think we may safely assume that the sulphur-content can be reduced to within fuel-oil requirements, and in view of a large number of experiments carried out under my instructions, I think we shall shortly find that the elimination of the ultimate sulphur in spirit also will be possible on a commercial scale.

To my mind, a matter of greater importance almost than the sulphur is the designing of a retort which will permit the extraction of the lighter, or what I might call the more delicate oils, separately from the heavier: in other words, a suitable retort system has yet to be devised.

In all such problems, which are obviously of national importance, I would urge collective rather than individual efforts, and hold that in so difficult a problem as organic sulphur offers, the co-operation of chemists accustomed to general organic questions would lead to satisfactory results more speedily than if investigations were undertaken by those versed in the chemistry of petroleum only.

I should be glad to see a collective effort made, and any suggestion put forward by the Institution to this end would receive my whole-hearted support.

J. W.

The Oil & Colour Trades Journal, vol. xlix, p. 677, remarks that "an interesting historical fact, apparently not mentioned by the author of the lecture reported on pp. 646–7, shows that the sulphur difficulty interfered with the use of the Kimmeridge shales a very long time ago. For, in the time of Queen Elizabeth, a statute was enacted forbidding the use of these shales as fuel in towns, on account of the objectionable fumes produced."

Thirteenth General Meeting.

A Meeting of the Institution of Petroleum Technologists was held at the House of the Royal Society of Arts on Tuesday evening, 21st March, 1916, Sir Boverton Redwood, Bart., D.Sc., F.R.S.E. (President), occupying the Chair.

The Members of Council present were Mr. Alfred C. Adams, Mr. Herbert Barringer, Prof. John Cadman, Mr. Andrew Campbell, Mr. E. H. Cunningham Craig, Mr. Arthur W. Eastlake, Mr. T. C. Palmer, Dr. F. Mollwo Perkin and Mr. Robert Redwood.

The Hon. Secretary (Mr. Arthur W. Eastlake) announced that the following gentlemen had been elected:

As Members:—Dr. Albert Ernest Dunstan, Dr. William Forbes-Leslie, John Cunningham Hope, Dr. William Fraser Hume, Albert Millar, Frederick William Moon (Transference from Associate Member), Arthur Matthew O'Brien, Capt. Frederic Calvert Vincent and John Henry Maliphant Young.

As Associate Members:—John Albert Bullbrook, Elliott Alfred Evans, Joseph Stuart Lawson, Charles Temple Orme (Transference from Student), Thomas Edwards Taylor, and Dr. Ferdinand Bernard Thole.

He also announced that the sixth number of the Journal was in the final stage of printing, and should be issued to the members at the end of the week. It contained 74 pages of text, with 8 of preliminary matter, a reduction, in response to the demand for economy, of 18 per cent., the previous number containing 100 pages.

The President said it was not unnatural that he should feel a little sad in realising that the present was the last occasion on which he would have the opportunity of occupying the Chair at a General Meeting of the Institution in the capacity of President, but he had the satisfaction of knowing that, thanks to the generous and sympathetic support extended to him by the Members at the Meetings over a period of two years, he was able to render to his successor an account of his stewardship which he hoped would be regarded as a not unsatisfactory one. The By-Laws of the Institution provided for the election of the President by the Council, but the new President did not take office until the action of the Council had been ratified by the Annual General Meeting, which would be held on the following day. Accordingly for a few more hours he was still the President of the Institution, and in that capacity he asked the Members to bear with him for a few minutes whilst he delivered his Valedictory Address, which, in

view of the prevailing war conditions and the scarcity of paper, to which the Honorary Secretary had just alluded, he had compressed within very narrow limits.

Valedictory Address by the President,

Sir Boverton Redwood, Bart.

In transferring to my successor the responsibilities which I accepted when you did me the honour to elect me as your first president, I desire to review very briefly the progress of the Institution, and to make a few remarks on our present position and prospects.

When I addressed you at the Inaugural Meeting two years ago I alluded to the undesirable position created by the lack of persons of our own nationality skilled in petroleum technology, which resulted in alien professional assistance being necessarily obtained in the conduct of petroleum undertakings in which British capital had been invested.

At that time the imminence of the terrible conflict in which we are engaged was not foreseen, and the importance of becoming independent of foreign help is immeasurably greater now than it was then.

In another respect we may be said to have fortuitously anticipated the trend of events, for since the Institution was founded there has been a general recognition of the paramount requirement of a far closer association of science and industry than has hitherto existed, and epoch-making action has been taken by the Government as the outcome of this tardy awakening.

Our Institution has been so constituted as to afford the fullest facilities for the application of science to the industry in which we are specially interested, and the work which the Institution has already done affords some indication of what we may hope to accomplish in this direction.

It is these considerations which led your Council to decide, soon after the inception of the war, that the continuance of the active operations of the Institution was fully justifiable, and would involve no unwise or unpatriotic diversion of energy into undesirable channels. The published transactions of the Institution, the complimentary allusions to our progress which have appeared in the Press, and the growing appreciation of our position and prospects, may be held to afford convincing evidence of the wisdom of the course adopted.

It may thus fairly be asserted that, notwithstanding the disadvantageous conditions created by the war, our original objects have already been achieved to an extent which even the most sanguine among us would scarcely have anticipated. At the Inaugural Meeting I ventured to say that we were entering upon our career with the brightest prospects, the realisation of which lay with the members themselves, and I have to-day the satisfaction of knowing that I was not unduly optimistic, and of being able to congratulate the members upon the manner in which they have taken advantage of the opportunities afforded by the Institution of advancing the interests of the Industry.

The papers which have been read are admittedly of a high order of merit, and have largely contributed to our knowledge of those branches of the subject of petroleum technology with which they have dealt. They have happily been of so varied a character as to furnish most valuable information from the geological, engineering, and chemical points of view, and have been contributed by men specially qualified by practical experience to speak with authority.

The monthly meetings at which these papers have been read have been remarkably well attended, and the discussions have been of a highly instructive character.

At these meetings the various departments of His Majesty's Government have been frequently represented, and official recognition of our work has thus been accorded to us.

In my brief presidential address I made reference to the proposal for the creation of an International Petroleum Institute, on which we had been consulted by the Government. That proposal originated in Germany, and it is needless to say, that there is no prospect of its being successfully renewed by that country. It is, however, worthy of consideration whether some action in the co-ordination of effort in the direction indicated might not usefully be taken in association with our allies, together with at least one of the neutral nations.

At the Inaugural Meeting I remarked that in our membership we should aim at high qualification rather than at numerical strength. Although our numbers have steadily increased, a glance through our list of members will suffice to show that through the joint action of our Election Committee and the vote by ballot of the members we have studiously followed the principle referred to. At the same time it is satisfactory to find that notwithstanding the necessarily heavy cost of the Journal our income has amply sufficed to meet our expenditure.

We have continued to enjoy the generous hospitality of the Royal Society of Arts, whose Council has permitted us to hold our meetings in their house, and I desire to acknowledge gratefully the encouragement which this has given us.

I also wish to express my deep appreciation of the help which we have received from the Press in general and from the technical Press in particular. At its inception the Institution was warmly welcomed as meeting a recognised want, and all possible help has been freely given to us in making our progress known. Without this invaluable support and co-operation we could not have made as great an advance in so short a time.

It has been no small part of our good fortune that we have been able to enlist the services of our able Honorary Editor and Librarian, Mr. W. H. Dalton, to whose devoted labours the admirable manner in which our transactions are published are due. The editorial articles which he has contributed to our Journal, and the introduction which he wrote for the brochure descriptive of the origin, progress and purposes of the Institution, are alike excellent. The manner in which additions to our steadily growing library are recorded and promptly made available for reference further indicates the very great interest which Mr. Dalton takes in the affairs of the Institution. We are indebted to the late Sir Thomas Bowring and other members for gifts of suitable works of reference, and to Mr. A. C. Adams (London & Thames Haven Oil Wharves, Limited) for the provision of bookcases and other furniture. In connexion with the library I wish to mention that our increasing list of exchanges with the publications of other societies affords welcome proof of the estimation in which our work is held.

To our Honorary Secretary, Mr. Arthur W. Eastlake, our special thanks are due, for the absence on military duty of our Assistant Secretary has largely added to his responsibilities, and has entailed daily attention to the routine procedure of the office. Mr. Eastlake has cheerfully borne this additional burden, and you all know how well the work has been done.

It only remains for me to acknowledge the support and assistance I have at all times received from the Council and Officers, individually and collectively, without which it would have been impossible for me to discharge the duties with which I was entrusted.

In these circumstances I relinquish my trust with a feeling of thankfulness for what has been accomplished, and in full confidence that the Institution having been firmly established on a sound basis, will continue to make satisfactory progress.

Prof. Cadman said that he was sure it was the wish of all the members that the best thanks of the Institution should be rendered to the President for his very interesting Address, but, as he was anxious to include a vote of thanks for the service rendered by Sir Boverton during his tenure of office as President, he would ask the members to allow him to express their views at the next meeting, when Sir Boverton had vacated the Chair. A better opportunity would then present itself of permitting, as they all desired to do, an expression of appreciation of the President's services. At the present moment he would merely say that the members were much indebted to the President for his interesting and able Address, and he asked permission to be allowed at the next meeting formally to express their appreciation of the great services rendered to the Institution by Sir Boverton.

The following paper was then read, illustrated by views and diagrams :—

The Natural Gas Industry, its Progress and Importance.

By J. A. Leo Henderson, Ph.D., F.G.S., M.Inst.M.M., *Member*.

The rapid rise of the natural gas industry during the past thirty-four years, and particularly during the past ten years, in the United States and Canada, and its steadily increasing relative importance compared with the liquid petroleum industry there, have drawn attention to the significance of the natural gaseous type of petroleum as a national asset.

In this paper it is proposed to review generally the progress of the industry, to note its chief modern features and tendencies, and to indicate the great importance of this wonderful natural fuel to all countries in which it may be found and developed. The geological, chemical and technical problems and practice, each warranting a special paper, will not be dealt with here.

Inflammable natural hydrocarbon gases which occur in quantity within the earth's crust may conveniently be classed generally as follows :—

1. Those associated with, and derived from, coal deposits.
2. Those associated directly or indirectly with petroleum deposits or bituminous shales,—"natural gas" of commerce. These can be regarded as natural gaseous petroleums, and form all known deposits of economic value.
3. The hydrocarbon gases associated with, and probably derived from, igneous rocks. These should also be mentioned, but as no commercially valuable deposits are known to exist or

have been recognized, no further reference will be made to this type of natural gas.

Natural Coal Gas.

While no evidence exists that the natural gas of any of the known profitable deposits in the world has been derived from coal deposits, yet in considering this question it is well to bear in mind that valuable natural-gas deposits are found within coal measures, in porous sandstones lying between or above coal seams, and further, that the gases derived from coal beds and those of many natural gas deposits have little to distinguish them in respect of composition and character. Ethane and the higher paraffins occur in many coals, and even the rare gases, helium, argon, krypton and neon have been found in both coal and natural gas.

Moreover, the facts that the amount of gas confined within coal seams is enormous in the aggregate, that the yield of methane of some seams during mining operations is in some mines equal to that of very large gas wells,—a yield which is continuous over a great many years,—and that coal gas "blowers," both from fissures in the immediate neighbourhood of coal deposits, and from porous beds lying above coal seams, in districts where no liquid petroleum or natural petroleum gas is known to exist, are at times very persistent and of great magnitude, indicate the possibility, indeed the probability, that accumulations of coal gas in porous strata do exist in profitable quantity, and should not be ignored.

As is the case with natural gas, coal gas is most abundant in the coals of Palæozoic age; although the gas is also present in the younger more bituminous coals and in lignite, it does not escape readily, whilst, in the absence of fissuring, an impermeable roof conserves the gas in the coal, and as would be expected, larger quantities of gas are found in anticlines.

These observations are made in passing, to indicate generally the features in common, but as previously remarked, no profitable coal-gas deposits have yet been recognized.

It seems strange, however, in these modern times of scientific effort, that nothing can be done to save, in part at least, and to utilise the enormous outflow of a valuable fuel, which must amount to many tens of millions of cubic feet a day in Great Britain alone.

"Natural Gas" of Commerce.

To the natural gas associated directly or indirectly with petroleum deposits or bituminous shales, the term "natural gas" has wrongly

been exclusively applied in the commercial and industrial world, because all known inflammable natural-gas deposits of economic importance belong to this type. It is to be greatly regretted, however, that this generic term has been thus limited in its application even in the practical world, for other natural gases are found in quantity, of which for instance, carbonic acid gas is won profitably, whilst others, such as nitrogen and the accompanying rare gases, may also come within the range of commercial exploitation. Protests which have been made in the past by scientists in the United States have been of no avail, for long-established usage acquires the force of law; in this paper therefore it is proposed to use the term "natural gas" in its commercial sense.

In the natural-gas industry only two broad divisions are usually recognized, viz.:—

1. "Dry" natural gas obtained from gas wells as the only or main product, and derived from large segregated gas deposits or "gas-pools." It is of chief commercial importance, and forms the bulk of the gas produced in the natural-gas industry. It is composed chiefly of methane, but ethane and other hydrocarbons are usually present in smaller quantities. By the accession of larger proportions of the heavier gases, "dry" gas acquires the character of the second type of gas, commercially termed "wet."

The general composition of the average "dry" gas of the Appalachian field is well illustrated by the following analyses of the gas supplied to Pittsburgh, gas from the mains having recently been analysed in an exhaustive manner by Burrell for the United States Bureau of Mines, both by liquefaction and fractionation, and by combustion methods. They represent the average composition of the gas from many hundreds of gas wells in West Virginia and Pennsylvania.

Pittsburgh Natural Gas—	Methane.	Ethane.	Propane.	(a)Butane.	N_2.	CO_2.
Analysis by liquefaction and fractionation ..	84·7	9·4	3·0	1·3	1·6	Tr.
Analysis by combustion	79·2	19·6	—	—	1·2	Tr.

The following analyses are examples from other fields:—

	Methane.	Ethane.	Propane.	(a)Butane.	N_2.	CO_2.
Hogshooter Field, Oklahoma (Kansas Natural Gas Co.)	94·3	—	—	—	4·6	1·1
McJewett Field (McKean Co., Pa.)	86·0	13·0	—	—	1·0	—
Tillanook, Oregon ..	2·0	—	—	—	97·9	0·1

	Pittsburgh.	Hogshooter Field, Oklahoma.	McJewett Field, Pa.	Tillamook, Oregon.
Specific gravity	·65	·58	·59	·96
Calorific value B.T.U. gross per cubic foot ..	1,208	1,004	1,159	21

The gas from Oregon resembles that from the famous Dexter well in Kansas, both being almost wholly composed of nitrogen, and this is given as an extreme and rare instance of natural gas which is practically incombustible. A few Californian Tertiary gases possess abnormal amounts of carbonic acid gas (as much as 30·4 % on the McKittrick field), which greatly reduces their heating value.

2. "Wet" or "casing-head" gas is chiefly produced from oil wells, being partly in solution, and partly in intimate physical association with liquid petroleum. "Wet" gas contains a greater proportion of the heavier and more easily liquefied petroleum gases, such as ethane, propane, butane, pentane and even higher members of the paraffin series, and is thus heavier than "dry" gas, whilst the lightest constituent, methane, may be wholly absent. This gas is termed "wet" in contradistinction to the "dry" gas, but this term does not imply the presence of water or moisture in the gas, but arose from the fact that during transportation through pipelines on surface, the heavier gases were condensed into a troublesome liquid which had to be removed by means of "drips."

"Wet" gas forms the basis of the natural-gas gasoline industry, which has rapidly assumed noteworthy proportions during the last few years.

The following analyses may be quoted as types :—

	CH_4.	C_2H_6.	N_2.	O_2.	CO_2.
Barren Co., Kentucky	23·6	69·7	1·3	—	2·5
Titusville Crawford Co., Pa. ("casing-head" gas.) ..	6·6	91·1	2·3	—	—
Riverside, W.Va., ... ("casing-head" gas.)	18·0	78·7	3·3	—	—

	Barren Co., Ky.	Titusville, Pa.	Riverside, W.Va.
Specific gravity	·91	1·01	1·38
Calorific value B.T.U. gross per cub. ft.	1,548	1,766	2,424

Natural-gas deposits throughout the world are found in close geological association with those of petroleum, although the immediate relationship is not apparent at first sight in the case of some of the large gasfields, in which the segregation appears almost complete.

Like petroleum, natural gas is found concentrated in quantity

exclusively within sedimentary rocks, usually in sandstones, conglomerates and dolomitic limestone; but it occurs also in fractured shales, and in fissures sealed towards the surface by impermeable beds. Large quantities are also found disseminated throughout shale beds.

Geologically considered, it may be said that the laws governing the accumulation and occurrence of liquid petroleum hold good equally for the gaseous type, the operation of the laws being affected in degree by the difference in the physical properties of the various kinds of petroleum from the solid to the gaseous forms.

In one striking respect, the occurrence of natural-gas deposits as a whole differs from that of petroleum, namely in the preponderant concentration of natural gas in the older pre-Tertiary sedimentary rocks, particularly in the Palæozoic, and the frequent complete separation of the gas from the liquid petroleum into large pools, compared with relative paucity of natural-gas segregations on a large scale in the Upper Cretaceous and Tertiary rocks, a very marked contrast when it is considered that as a whole, these younger sedimentaries far exceed the older rocks in the production of liquid petroleum outside of the United States.

This is an important feature to bear in mind in exploration work, and in considering the probability of the occurrence of natural-gas deposits of value in various countries in which this mineral has not yet been found in quantity.

As in the case of petroleum, a notable difference exists between the structure associated with large natural-gas deposits occurring in the older and consolidated rocks and that of natural-gas "pools" in the softer Tertiaries, namely that while in the former the gas is usually found under very gentle arches or terraces with hardly perceptible dip, usually less than 1°, the deposits being therefore often of great lateral extent, the accumulations in the more plastic Tertiary strata are often found in steep and narrow anticlines or domes, and form relatively small "pools."

It follows from the geological association with petroleum that natural gas is likewise as widely distributed geographically, occurring within practically every country in the world, but outside of North America, it is seldom found in large segregated deposits of economic value. This appears to be due to the fact that in other countries, nearly all of the large profitable oil deposits so far exploited have been found in the younger rocks, chiefly Tertiaries, under structural and other conditions such as those already mentioned.

Evolution and Progress of the Industry.

Like petroleum, natural gas has been known to exist from the very dawn of civilization in China, India and Persia. The Chinese are said to have been the first to utilise this fuel on a large scale more than 2,000 years ago. Strange though the tardy development of the oil industry has been, historically considered, still more singular is the fact, that although the usefulness of gas as fuel has been known for thousands of years, the development of the industry, as such, has only taken place within the past 35 years, and then almost exclusively in North America, other countries having ignored the value of this remarkable fuel.

Signs are not wanting, however, that other countries such as Hungary, Roumania and Russia have awakened to its importance, and that in the near future their natural-gas resources will be exploited in accordance with modern methods, resulting in the establishment of the industry as an important factor in the economic life of these countries.

The natural-gas industry at the present time is practically confined to the United States and Canada, and therefore its progress and importance must be studied from its record in those countries.

To the United States belongs the credit of first recognizing the great value and possibilities of this mineral, and of establishing the industry on a firm basis. Thus, natural gas by 1913 had risen to the sixth place in importance among the mineral products of the United States (excluding clay and cement), only being exceeded in value by copper, petroleum, pig-iron, and coal, and approximately equalling the value of the gold production. This, in the greatest mineral-producing country in the world, and the second most important gold-producing country, is no mean achievement.

Natural gas is first recorded as being used for lighting and heating in 1821 in New York State, while in 1841 a large quantity of the gas which was encountered in borings for brine in the Great Kanawha valley in West Virginia was utilised for evaporating the brine. In Ohio it was first used for manufacturing purposes in 1863, and the first pipeline conveying gas for distribution to domestic consumers was constructed in 1872 to Titusville, Pa., 5½ miles in length. Although gas was introduced into Pittsburgh in 1876, it was not until the completion in 1883 of an eight-inch high-pressure pipeline, 35 miles long, to Bradford, Pa., that the industry can be said to have really started. Since that time the progress of the industry has been remarkable, in spite of the fact

that from 1883 to 1891, a period of reckless waste and misuse of the gas intervened (the result of unlimited competition for the sale of apparently inexhaustible supplies of the gaseous fuel), which threatened to permanently cripple the industry and destroy public confidence.

Fig. 31. Gas-well, closed pressure 405 lbs. per inch. Initial flow 5,000,000 feet daily.
Note.—At the opening of the valve, the current is at first opaque with condensed and frozen moisture, but soon becomes invisible, though resisting a blow like a solid bar.

Prior to 1891 the gas was sold at "flat rates," i.e. unmetered, at almost nominal prices, but with the gradual introduction of meters from 1891 onwards, and the reorganization of the industry, the supplies were regulated, and payment according to consumption was inaugurated. The evil effect of the years of misuse were

keenly felt until about 1898, when the industry appeared to take a new lease of life, and rapidly rose from a yearly value of about $15,296,000, or £3,143,000, to over $94,115,000, or £19,336,000, in 1914, being an increase of over six times during 16 years.

The total production of natural gas in the United States up to the end of 1914 from the inception of the industry exceeds $1,056,000,000, or £217,000,000.

As Canada produced in 1914 gas to the value of $3,651,256, or £750,259, the total value of the industry in the United States and Canada in 1914 was $97,766,780, or £20,087,000, while the value of the total natural gas-production of both countries to the end of 1914 amounts to $1,077,591,178, or £221,423,379.

In the natural-gas fields of the United States, the Eastern Fields comprising New York, Pennsylvania, West Virginia, Kentucky, Ohio, Illinois and Indiana; the Mid-continental Field, Kansas and Oklahoma; the Gulf Field, Louisiana and Texas, and the Californian Field, contributed practically the whole of the production in 1914, but no fewer than twenty-two States yielded gas in profitable quantities. The gas is derived from Palæozoic rocks on the Eastern and Mid-continental Fields, but in Louisiana and Texas the gas deposits are found in the Cretaceous and Tertiary, and in California the gas is of Tertiary age.

The extent of the gasfields in the United States has been estimated by the Geological Survey at 9,365 square miles, and in 1914 over 10,600,000 acres were controlled by gas producers. The production in 1914, over 96 per cent. of the world's output, amounted to 591,866,733,000 cubic feet, say 13,211,300 long tons.

The question of gas reserves in this industry is a vital one. Largely through force of circumstances, owing to repeated failures on the part of small producers to maintain adequate gas reserves to meet the very fluctuating demand for the product during the year, and the necessity for controlling large areas and pipeline systems in order economically and successfully to supply large centres of population, the industry has come under the control of large corporations, with, it must be admitted, beneficial results. Their far-seeing policy in building up large gas reserves, and in promoting the conservation of the product, has also placed their natural-gas securities on a firm basis, but more sympathetic treatment by the public is necessary if the best is to be got from the industry.

Taking the West Virginia Field as an example, it has been estimated that enough natural gas is now developed, and held in

reserve, to provide for all markets depending upon the field for fifty years to come, if proper use is made of the gas.

In the best gasfields, wells with initial flows of 1,000,000 feet a day are of frequent occurrence, while initial flows from 10,000,000 to 30,000,000 feet are not uncommon, and on some fields gigantic wells, with estimated initial productions at the rate of 50,000,000 to nearly 100,000,000 feet (say 1,140 to 2,280 long tons) a day

FIG. 32. Gas-well, closed pressure 380 lbs. per inch. Initial flow 7,000,000 feet per day.

have been drilled. In new fields, where the gas commands a low price, initial flows of less than 1,000,000 feet a day are not considered remunerative, but in old fields, in sands possessing good "staying" power, wells yielding 100,000 feet a day and less prove profitable. Gas wells have been known to produce profitably for twenty years and more, but the average life is much lower, being on some fields only three or four years or even less. The life

depends upon the nature of the reservoir-rock, the gas pressures, the extent to which the well is drawn upon, and the care of the well.

The greatest ascertained yield of any individual gas well, of which the author has knowledge, is that of a well drilled to the Gordon Sand in Pennsylvania, almost 3,000 feet in depth. The production in 7½ years was about 7,781,946,000 feet, 177,000 long tons, and the well was still producing about 1,000,000 feet a day at the end of that time. If this production be valued at the average price of natural gas in the United States during 1914, namely at about 16 c., 8d., per 1,000 feet, the total value of the production from this single well would be $1,167,292, or almost £250,000.

Waste and Conservation.

Reference has been made to the waste, of the most prodigal and unpardonable kind, which has disfigured the history of the industry. Even at the present time a large amount of preventable waste takes place on the Eastern Fields, estimated by I. C. White at 200,000,000 feet a day in West Virginia alone. In the Mid-continental Field, of recent years, the loss of gas has been enormous, and it is estimated by authorities that in the Cushing Pool alone, over 2,000,000,000 feet have been wilfully wasted in the years from 1913 to 1915, while A. J. Diescher's investigations early in 1915 showed the waste of gas to be no less than 340,000,000 feet, or 8,000 long tons, a day. Indeed J. C. McDowell has estimated that the value of gas wasted in the Oklahoma fields during recent years exceeds that of the whole petroleum production.

The dissipation of natural gas in California and on the Gulf Coast Field has of late years taken place on almost as large a scale as in the Mid-continental Field.

Almost as startling as the waste of "dry" gas, is that of the recoverable natural-gas gasoline escaping as gas. Burrell has estimated that in 1913 the value of such wasted gasoline in Oklahoma alone was 10 % of the entire crude oil production. The enormous extent of the loss of this product in the past on the other oilfields of the United States can only be conjectured.

The oil operators are largely to blame, but it appears difficult to remedy this state of affairs unless the State is willing to recompense the oil operator, in part at least, for his extra expenditure in shutting in the gas in regions where no market exists for the gaseous product, or unless the State carries out the work of shutting off the gas. Apart from State action in passing strict conservation-laws to prevent such waste, it is most gratifying

to note the practical action of the Bureau of Mines in appointing an expert to advise operators, and in successfully demonstrating by practical work the efficiency of the well-known "mudding up" process for sealing the gas sands lying above prolific oil sands. It has been estimated that in this way the Bureau of Mines has saved from dissipation gas of a value exceeding $15,000,000, or sufficient to defray several times the total cost of the Bureau of Mines from its beginning.

The waste of "wet" gas or petroleum-vapour-laden gas from oil wells has been a constant one on every oilfield of the world throughout the history of the oil industry. The large wells of

FIG. 33. Gas-well, closed pressure 530 lbs. per inch.

Tertiary oilfields in particular, yield when "brought in" such immense volumes of gas as to be a source of danger to the neighbourhood for a considerable distance around. The oilfields of California, Louisiana, Mexico, Galicia, Roumania, Russia and the East Indies, furnish abundant evidence of the dissipation on a large scale of a valuable fuel which it seems should not be beyond the ingenuity of man to lessen very considerably or minimize in most cases.

Where there is a market for the gas, successful oil and gas separators have been designed for dealing with large flows of gas and oil under great pressure, and thus a remedy is possible by co-operation between oil and gas companies.

The storage of superfluous gas in dry or exhausted sands in wells in the neighbourhood is being tried in California. An appreciable loss by absorption and permanent retention in the "dry" sand and other rocks is bound to take place, but the result of the experiments will be looked forward to with interest.

An insidious form of waste, rarely noticed, but a very real one, is what is termed as "underground waste," i.e. leakage of gas into strata lying above the gas sands, and thence escaping imperceptibly to the surface. This is caused by imperfect packing or casing, and can be remedied by proper care.

One of the worst forms of waste, and of particular importance to the State, is the leakage from pipelines of the transportation and distribution systems. This, according to J. C. McDowell, will average, in the case of most companies, 25 % to 40 % of the gas delivered into the main lines at the field. Indeed, A. J. Diescher has recently given instances of discrepancies between the quantities of gas as measured when entering the main lines, and the amounts metered as sold to consumers, of 30 % to 75 %, and has quoted the case of one large company in particular, possessing 200 miles of trunk lines and 100 miles of distributing lines, serving 25,000 consumers with a maximum of 25,000,000 feet of gas a day, whose annual loss of gas was 35 %. When it is considered that some companies distribute almost 100,000,000 feet of gas daily, and that the gas wasted by leakage has been greatly enhanced in value by reason of large capital expenditure and much labour, it will be seen what a serious factor this is, not only to the operating companies and to the natural-gas industry, but to the State itself. If, of the amount of natural gas distributed in the United States in 1914, only 10 % be taken as an average loss through pipeline leakage, the amount of gas thus escaping would equal 65,700,000,000 feet, of a value, at 16 c. per 1,000 feet, of over $10,500,000, or say £2,160,000, during the year. The loss is chiefly due to the destruction of the rubber gaskets in the main pipelines through oil, natural-gas gasoline and water, but corrosion of the pipelines plays a great rôle, and in a less degree, split joints and "blow-outs," while in the town distribution systems electrolysis is active as a destructive agent. Owing to the fact that the majority of transportation and distributing companies do not measure accurately, if at all, the gas delivered into the pipelines on the field, the enormous proportions of their pipeline leakage has not been fully realised. Hitherto no cheap and accurate method of measurement of large quantities of gas under high pressure has been available, but with the introduction

of the orifice meter, which has of late years been perfected, and which is simple, cheap and efficient, and is fitted with self-registering instruments, the losses of leakage can be readily detected and, as far as possible, remedied. A new form of gasket, which is less affected by oil and gasoline than rubber, is now being used, but the lack of an adequate price for the natural gas has much to do with the inability of the natural-gas companies to expend such amounts of money as are necessary to construct pipelines capable of giving the highest efficiency, and to maintain them in perfect condition.

Inefficient utilisation by domestic consumers, but especially wasteful use by certain industries, is another important source of waste. In the case of domestic consumers, this is being gradually but slowly lessened by the steady increase in price, which causes more efficient appliances to be used, and also by their education by the gas companies in the best methods of burning the fuel. The same holds good to much less degree in the case of the brick, glass, cement, iron, zinc, and other works, which purchase enormous quantities of natural gas. Even at the present time, prices ranging from only 1 c. to 5 c. per 1,000 feet are common, which encourages wasteful methods, but in cases where the supplies of gas are diminishing, these industries have been able to use natural gas profitably at prices ranging between 12 c. and 30 c. per 1,000 feet, which indicates a very large scope for improvement in the general practice. The carbon-black factories in West Virginia however, even in 1914, used no less than 20,704,191,000 feet of gas, for which only 2·07 c. per 1,000 feet was paid. As 1,000 to 1,200 feet of gas is required to produce a pound of carbon black worth only a few cents, this misuse of such a valuable fuel has aroused strong protests from those interested in the conservation of natural gas.

Generally speaking, it would appear that the remedy for the prevailing waste of this natural product will lie not only in the enactment and enforcement of reasonable conservation laws, but equally in the recognition by the general public that fair treatment must be accorded the industry by them in the direction of adequate prices, without which relatively little improvement can be expected.

The question of conservation is a very difficult one, especially from a legislative standpoint, since impracticable or unduly harsh legislation may kill the industry. This, however, is being studied in the United States with the utmost care, by able and practical men acquainted with the industry, and a satisfactory outcome may be expected in the near future which will prove of the greatest

value to other countries in dealing with the problem. Much credit must be given to the public spirit shown in this matter by prominent men in the Natural Gas Association of America.

Use of Natural Gas.

At the time of the greatest misuse and waste in the natural-gas industry, in 1889, it was estimated that 552,150,000,000 feet was sold for $11,000,000, or an average price of about 2 c. (1d.) per 1,000 feet, or less than 4s. a long ton, domestic consumers taking only 11·3 % of the gas, the rest of this enormous quantity being used in the iron and other industries in the place of cheap coal; whereas in 1914, only 7 % greater quantity of gas (591,866,733 feet) realized over $94,000,000, the average price being 15·9 c., 8d., per 1,000 feet, or about 30s. a long ton, the 2,073,099 domestic consumers taking no less than 34 % of the gas at 28·04 c., 1s. 2d., per 1,000 feet and paying over 60 % of the total value realized.

While natural gas is an ideal fuel for industrial use, for domestic purposes it is pre-eminent for house-heating, for cooking and lighting. For domestic purposes, however, the costs of distribution and of the upkeep of the pipeline systems are very heavy, whilst the occurrence of severe "peak" loads, and the necessity of supplying ample gas at all times, demand a large outlay which for the greater part of the year is unproductive. These considerations, coupled with the prevailing low prices, yielding a return incommensurate with the outlay and risks involved, still cause gas to be sold at low rates to industries in large quantities, chiefly on account of the lesser cost of piping and distribution, and the lack of stringent conditions as to continuous service, whilst the desirability for equalizing as far as possible the irregularities in the load during the year is also a factor. It is found that the domestic demand at times of extreme cold in winter reaches as much as twelve times that of the summer months, whilst during the day the load is subject to variations up to 100 %.

The whole history of the industry shows that natural gas should be restricted as far as possible to domestic purposes, to the generation of power by means of gas engines of moderate size, and to use in such smaller high-class industries for which it is especially suited, for all of which purposes an adequate price can well be paid, as the labour-saving features can best be taken advantage of where individual, as opposed to collective, organized effort is being exercised.

An equitable price, apart from the special considerations of the heavy cost of maintaining an ever-ready service for small

and large consumers under violently fluctuating conditions of demand, should be such as to allow of a proper conservation-policy being carried out in all departments, e.g. in the field, in transportation, in distribution, and in the use of gas, and it is hoped that in the United States and Canada it will be soon recognized that upon this factor depends largely the success of the efforts now being made to ensure efficient conservation.

The use of natural gas for household purposes is of very great value to the economic life of a nation, by reason of the great saving in labour which it effects, as distinct from the economy of time and expenditure, and the increased comfort, health and general standard of life which accrue. It is found that it saves the labour of one servant in middle-class households, a very important consideration to any country, especially where labour is scarce, by releasing labour for productive work. The advantages to the individual householder are particularly felt in very cold or very hot countries, and where good household servants are rare and expensive.

For industrial purposes natural gas has been used instead of other fuels in almost every direction. As a direct fuel in the large industries it has been proved that from 20,000 to 26,000 cubic feet of gas, according to the method of utilization, is the equivalent of one long ton of good coal, and thus its chief saving over other fuels is only its increased efficiency as a fuel, the saving in labour being in such case relatively insignificant. Hence, in districts where cheap coal is available, say at $2, or 8s., a ton, natural gas cannot compete as a direct fuel, except at very low prices, say 12 c., 6d., or less, per 1,000 feet.

At such prices the gas cannot be profitably sold if long-distance transportation is involved, and if the best principles of conservation are to be carried out. For power purposes, the gas engine should always be used, for it consumes only from 9 feet in large engines to 20 feet in very small engines per hp. hour, compared with a consumption of 16 to 40 feet and more in the case of steam boilers, or a saving of 100 % in gas. The saving is especially marked in the case of small gas engines as compared with ordinary steam practice.

Price of Natural Gas.

As already indicated, the price of natural gas has increased by about 14 times since 1889, and is still steadily advancing. For domestic use, the average price has increased by 5½ cents per 1,000 feet since 1906.

In spite of this, the present price is still quite inadequate on the average, and contributes a great deal to the perpetuation of the waste on the field, in distribution, and in the use of the gas by consumers, for there is no inducement to the producers to expend large sums of money upon conservation, when the expenditure is not justified by the prospect of commensurate reward. More attractive rates now prevail in many towns, with a consequent improvement in service, and in the stability of the supply companies, which are thus enabled to conserve their gas, and reserve it almost exclusively for domestic use. The low price for gas, coupled with the enormous consequent consumption and rapid depletion of the gas fields, has caused the downfall of many enterprises during the brief history of the natural-gas industry, and the public is now beginning to realize the great and permanent disadvantage and loss to individuals and to the community, which has inevitably resulted. The evil influence of the unlimited competition by producers, and of consequent extremely low prices and boundless waste during the early days of the industry, seem almost impossible to eradicate, for, on the one hand, fear of the stability of the supply, and on the other the apparent inexhaustibility of some wells, and the idea that since the gas comes from the earth it can cost the producer nothing, both operate at the opening of a new field to depress prices. It thus happens that most communities in the United States and Canada towns most strenuously refuse to pay even half the price which they willingly pay for artificial, for natural gas, though possessing twice the calorific value and none of the poisonous or harmful ingredients of the artificial fuel.

Even in 1914 the average price was only 15·9 c., 8d., per 1,000 feet, or 30s. per long ton, or, if considered as a liquid, 2s. 4d. a barrel of 35 gallons or a little over ¾d. an imperial gallon. These figures are given for comparison with the price paid for highest grade of petrol, with which it can best be correlated.

Comparing the average domestic price of 28 c. (1s. 2d.) paid for natural gas with a heating value of over 1,000 to 1,100 B.T.U. with the price of 2s. 4d. paid in London for manufactured gas, which possesses only half the heating value, it is seen that if sold on a thermal basis the price of natural gas is only one-quarter of that paid for London gas, or equivalent to 7d. per 1,000 feet.

Periodic revision and regulation of prices has of late years been made by the Public Utilities Commissions which have been established by most States in the United States, and in most Provinces in Canada. The advent of the Commissions has been

welcomed as an improvement upon the prevailing state of affairs. So far their decisions appear to have operated fairly and satisfactorily.

"Wet Gas," The Natural-Gas Gasoline Industry.

"Wet" or "casing-head" gas, which is obtained chiefly from petroleum wells, contains in addition to methane and ethane, the heavier hydrocarbons propane and butane, and also varying amounts of pentane, hexane and heptane. It may attain the high specific gravity of 1·64 (air = 1).

The heavier gases readily condense into liquid form under pressure and cold, and this feature has been utilised commercially on an increasingly important scale since 1904, for the extraction of the liquid hydrocarbons, the "natural-gas gasoline" of commerce.

The rapid rise to importance of this industry in the United States since 1911 can be seen from the following table, no earlier records of output being available :—

Year.	Plants.	Gas Used.		Gasoline Produced.		Average Yield in U.S. gallons per 1,000 ft. of gas.
		Thousands cub. ft.	Value.	Quantity U.S. gal.	Value.	
1911	176	2,495,697	$176,961 £36,361	7,425,839	$531,704 £109,254	3·00
1912	250	4,687,796	$331,985 £68,296	12,081,179	$1,157,476 £237,838	2·60
1913	341	9,889,441	$566,224 £116,350	24,060,817	$2,458,443 £505,166	2·43
1914	386	16,894,557	$889,906 £182,872	42,652,632	$3,105,909 £638,200	2·43

Within four years, therefore, the production and value of the industry have increased almost six-fold.

To illustrate its importance, it may be pointed out that the production of gasoline from this source in 1914, over 1,000,000 barrels, was equivalent to about one-third of the total consumption of motor-spirit in the United Kingdom in that year. In the United States however, for 1916, the consumption of motor-spirit, it has been estimated, will be over 23,000,000 barrels, so that as yet the natural-gas gasoline industry can only supply a small proportion of the home demand.

The average price realised per U.S. gallon was 10·22 c., 5d., in 1913, and 7·28 c., 3⅜d., in 1914, but the price has increased since in sympathy with the great demand for motor-spirit. The basis for gasoline quotations is 68°—70° B., ·71 to ·70 sp. gr.

Three extraction methods are in use :—

1. Compression accompanied by cooling.
2. Cooling by means of a refrigerant at low pressures.
3. Absorption in heavy oil, under pressure.

Nearly the whole of the gasoline output is produced by the compression method, which owes much of its success and wide-spread use to the initiative energy and ability of the officials of the Bessemer Gas Engine Company. Two-stage compression with intermediate cooling, suffices for the treatment of most gases rich enough in gasoline to be worked profitably, but sometimes four stages are necessary. The following are the products :—

(1) The first-stage compressor product, or ordinary gasoline.

(2) The "wilder," more volatile second-stage product, which is handled as a lighter gasoline, and is blended with heavier refinery naphthas.

(3) The liquid condensable only by the higher-stage pressures, "liquefied natural gas" or "gasol" of commerce, which must be handled as a gas, and is confined and distributed under high pressure in steel containers.

(4) The residual gas which is sold as "dry" gas, although possessing a very much higher calorific value, as much as 2,300 B.T.U. per foot, than ordinary "dry" gas from wells.

The products (1) and (2) are composed chiefly of butane, pentane and hexane, and are sold as gasoline.

Liquefied natural gas or "gasol" is composed chiefly of butane and propane, and has a specific gravity of 0·6. Its calorific value as a gas is high, 2,400 B.T.U. gross, and when burnt with oxygen the flame temperature is said to exceed that of the oxyacetylene-flame. It is sold for general and household purposes, in steel containers of about 1 foot or 40 lb. capacity, which yield about 400 feet of gas, and at the point of production was worth until recently about 10 c., 5d., per U.S. gallon. It has been successfully in the past instead of petrol for motor vehicles, and doubtless will be useful in this direction at the present period of high prices and scarcity of motor fuel.

While the range of liquids varies from 57° B., 0·747 sp. gr., to 100° B., 0·596 sp. gr., most natural gas condensates have a gravity of 80° to 94° B., ·66 to ·62 sp. gr. At present practically all natural-gas condensate is blended with lower-grade refinery naphthas of 58°—60° B., ·74 to ·736 sp. gr., thus converting the latter into high-grade motor-spirit. The condensate should be blended with naphtha as soon as possible after it has been made. in order to get full advantage of the slower rate of evaporation

which is effected by blending, as the losses by evaporation of the condensate are very considerable. All storage-tanks should be painted white or light grey, and protected by a light building to minimize evaporation.

The best location for a plant is near to an oil refinery, and beside a railway, so that a ready supply of naphtha for blending is available, and transportation, with a minimum of evaporation, of the products in tank-cars, is cheap and easy. Plants situated at a distance from a refinery or railway are at a serious disadvantage, but in Oklahoma condensate, as such, has been piped as far as twelve miles, and for greater distances by dissolving it in crude oil, and thus transporting it by pipeline to a refinery, where it is recovered in the usual way.

The Bessemer Gas Engine Company gives the cost of a two-stage compressor installation complete ready for beginning operations, exclusive of field piping, to treat 1,000,000 feet of gas a day, at $14,500, £3,000. This would be run by three men, exclusive of field work. Assuming a high extraction of three gallons per 1,000 feet, and the low price of 6½ c. per gal. for the product, it is estimated that after paying all costs of operation, allowing for interest, depreciation, gasoline losses, and a wide margin for contingencies, a balance as net profit of $3,600 would be available, or 25 % on the cost of installation.

Net profits of 50 % and 100 % per annum have been realized where location and conditions are favourable for the purchase of gas, for the sale of residual gas, and where the price of the product is about 10 c. per gal. and over.

One large company in Oklahoma produces as much as 35,000 U.S. gallons of natural-gas gasoline a day, while gas escaping from a single oil-well has yielded gasoline to the value of $500, £103, a day. For success in operation, it is estimated that at least 125,000 feet a day must be available for treatment.

The refrigerative process by means of ammonia at low pressures has been successfully applied in at least one plant. One company in California extracts 1,200 gallons of condensate from 300,000 feet of gas a day by this method.

The absorption process is working successfully on a large scale in the treatment of very large quantities of lean gas, containing only about 0·1 gallons of recoverable gasoline per 1,100 feet, i.e. too poor in gasoline to be capable of profitable treatment by the compression method.

Specific gravity alone is no criterion as to natural-gas gasoline content or yield, for with a relatively low specific gravity, a gas

may contain heavy condensable hydrocarbons in profitable quantity; whereas another gas with a specific gravity of say 1·5 may be composed almost wholly of methane, propane and butane, and be thus unprofitable to work.

G. A. Burrell, of the U.S. Bureau of Mines, after a careful study of field results and after completing a series of experiments, considers that a "wet" gas must possess at least a specific gravity of 0·95 (air = 1) and a claroline absorption of 40, in order to be profitably utilised for the production of natural-gas gasoline. This holds good doubtless where natural-gas gasoline is recovered as the only or main product by means of compression and cooling, and where the gas in most cases must be purchased, but under other circumstances, where large quantities of gas belong to the operator, and are being transported under high pressure, and if the natural-gas gasoline is won as a by-product, it is claimed that "lean" gas can yield good profits by the adoption of a suitable method of extraction of the gasoline.

In the early days of the industry, serious accidents occurred, not only in the storage, but during transportation of the very unstable products which were then obtained, so that the chief of the Bureau for the Safe Transportation of Explosives took control of the matter, and has enforced compulsory rules in regard to transportation. The vapour-pressure at 100° F. (38° C.) was taken as the basis, and only products with a pressure of under 10 lbs. per inch may be shipped in bulk, and then only in standard tank-cars. Products yielding higher pressures must be confined in special metal drums, or, when the pressure exceeds 25 lbs., must be treated as compressed gas and confined in cylinders.

The life of "wet" gas wells is an important factor. It may be said that, in general, the life of "wet" gas wells on any field will be proportionate to that of the oil-wells, and that a long-lived oilfield which produces "wet" gas will mean a long-lived natural-gas gasoline industry. Some oil wells have produced oil and gas under vacuum for as long as 29 years in West Virginia.

The character of the products is causing a change in the nature of the royalty basis to take place, for the tendency of owners of "wet" gas is now to charge a percentage royalty on output, as in the case of oil, instead of a flat rate per well, or per 1,000 feet of gas, as is usual in gas practice.

Apart from the enormous and ever-increasing demand for motor-spirit, and the probability that even the lightest condensates will be used for purposes of propulsion in motor vehicles, the lighter products also possess qualities which commend them

particularly for use in the rubber, varnish, paintmaking, dyeing, cleaning and other trades and industries.

Nine States contributed to the production in 1915, Oklahoma, West Virginia, California and Pennsylvania leading. The increased production of Oklahoma and California was remarkable.

Furnishing, as it does, a means of minimizing a public waste, and at the same time of extracting large profits from material which has hitherto proved a source of trouble and danger to oil operators everywhere, the industry has attracted much attention from other countries, and in Japan alone three large operators have plants in successful operation.

It may be said that the natural-gas gasoline industry forms the connecting link between the petroleum and natural-gas industries, and it appears destined to attain a position of very great importance in all petroleum-producing countries of the world.

By-Products of Natural Gas.

Messrs. Cady and McFarland have found the rarer gases helium (up to 1·84 % in Kansas gas), argon and neon in many of the natural gases examined by them, and conclude that it is probable that these are universal constituents of natural gas. It is also stated that considerable quantities of helium and neon have been extracted from Kansas gas for experimental purposes.

The same authors suggest the use of natural gas with a high percentage of methane as a starting point for the manufacture of various chemical substances in the world of organic chemistry, such as formaldehyde ($C H_2 O$), a valuable antiseptic, and so forth. The manufacture of hydrogen on a large scale has also been attempted, with partial success. Calcium cyanamide, $CaCN_2$, a very good fertilizer, has also been made on a laboratory scale by Professor Duncan, from natural gas rich in nitrogen. If calcium carbide, necessary for the reaction, were cheaper, the process would become commercially feasible.

Recently I. N. Krapp has suggested the manufacture of methyl alcohol from natural gas according to a method developed by laboratory experiment.

Hitherto no practical result on a commercial scale appears to have been achieved in the extraction of by-products. Any success would prove of the greatest value to those fields where no ready market exists for natural gas as a fuel.

The research committee of the Natural Gas Association of America suggests research by trained chemists with a view to

evolving methods of producing acetylene, chloroform, carbon tetrachloride, wood alcohol, and other products.

Statistics.

In natural-gas production the British Empire ranks second in importance, contributing through Canada 3½ % of the world's production.

Apart from Canada, no large deposits of value have been found and developed within the Empire, although natural gas is found in nearly every State, and in a few instances has been put to practical use on a very small scale.

In Canada the history of the industry began only in 1892, and until recently the deplorable features of the industry in the United States have been reflected on a smaller scale. The Palæozoic rocks of the Ontario Peninsula had yielded practically the whole supply until 1912, when new gas discoveries and developments in both Eastern and Western Canada—New Brunswick and Alberta—began to make themselves felt.

The new gasfields in Western Canada are likely to take a place among the largest and most important in America, and to prove an asset of the greatest value to the country. Fortunately, the largest producing and distributing company there is controlled by a man who is an authority on the natural-gas industry, and wise restrictive regulations have been made by the Government and by large landowning companies, so that it is hoped that the development of this great natural resource will be carried on in the most efficient and beneficial manner. The City of Medicine Hat, however, which possesses a number of large gas wells within its own town lands, has not taken advantage of the experience of the United States, but has sold its gas at extremely low rates, and in several cases has given free gas to industries for a period of years. While this policy is always successful from the point of view of a town at first, the inevitable depletion of the natural-gas deposits will take place the sooner, accompanied by the usual consequences. Further, extremely cheap, and especially "free" gas, always means wasteful use, and is opposed to the best interests of the country.

Of other parts of the Empire, mention should be made of the natural gas possibilities of the great Triassic-Jurassic Artesian basin of Australia. In this, the largest artesian basin of the world, numerous boreholes yielding large flows of water have been sunk in Queensland, New South Wales and South Australia. The principal water-bearing sandstone is of great but varying

thickness, from 100 to 800 feet, and appears to be as massive and persistent over a very great area as is the well-known Dakota sandstone of the extensive Cretaceous artesian basin in North America, which extends from Colorado in the United States as far as the Athabasca River in North-Western Canada. Sandstones of such persistent massive type, have, until recently, been considered unpropitious to the accumulation in profitable quantities

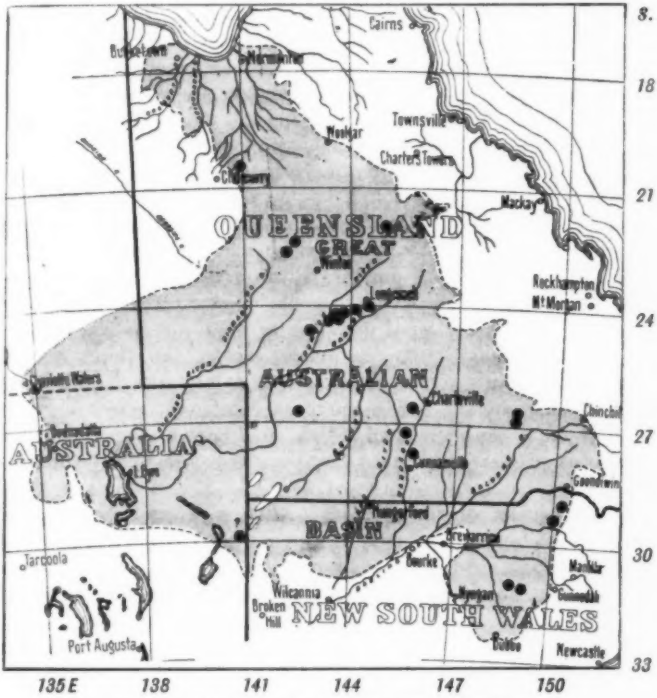

FIG. 34. Gas-flows in the Great Australian Basin.

of petroleum and natural gas, especially when apparently saturated throughout with water, but the recent discoveries of natural gas in great quantity in the Dakota sandstone in Canada, and also in the United States have proved the fallacy of this assumption. The rocks of both basins are in general equally free from marked disturbances, or possess only very gentle undulations. Whereas in America the Dakota sandstone has been proved gas-bearing, fortunately within relatively shallow depths, the artesian sand-

stone of Australia has so far yielded natural gas only where tapped by boreholes at great depths, usually between 3,000 ft. and 4,000 ft. although the gas-yielding Narrabeen borehole is only 1,650 ft. deep. No fewer than 15 boreholes have yielded strong flows of inflammable natural gas in Queensland and New South Wales in association with mineralized artesian water, and in the case of four of these wells small quantities of petroleum accompanied the gas. Natural gas has been found in wells distant more than 850 miles north and south, and 350 miles east and west, of each other. Indeed, no less an authority than Mr. J. B. Henderson, in his evidence before the Interstate Conference on Artesian Water, in 1912, gave it as his opinion that natural gas is found in greater or less quantities nearly all over the State of Queensland.

The structural geology of the basin does not appear to have yet been worked out in detail, but presumably the borehole sites were selected with regard to the synclinal structure associated with artesian water. In all cases in which natural gas was struck it was eventually drowned out by the accompanying artesian water, and apparently it was never possible to case off the gas. That flows of gas should have persisted as they did in considerable quantity for many years, as in the case of the Roma well in Queensland, can only be characterized as remarkable, when the great weight of the superincumbent column of water in these deep wells is considered, and if the well-known ease with which an influx of water into even large gas wells effectually shuts off the flow of gas be borne in mind.

The quantity of gas evolved is often so great in comparison with the volume of the flow of water, that it is evident that the gas must exist chiefly in a free condition, and not only in solution, for natural gas is soluble in water only as approximately to 3 % by volume.

The gas present is always under great pressure, which in some instances must exceed 2,000 lbs. per inch, and in the case of the Mineral Oil Company's borehole in Queensland a pressure at surface of between 200 and 300 lbs. per inch was observable. Very strong gas flows of up to 1,000,000 feet a day are reported to have been encountered, and in two instances,—those of the Roma and Narrabeen,—the gas was utilised for a short time for domestic purposes.

The following analyses of natural gas from boreholes in the Great Australian artesian basin will be of interest.

	Paraffins.	Benzenes.	Olefines.	CO_2.	CO.	N.
Roma, Queensland ..	82·8 % (Ethane 9·8 %)	5·8	1·5	1·5	5·8	3·4

	CH_4.	CO_2.	N.
Yowie, N.S.W. ..	50·0 %	—	50·0 %
Gilgooma, N.S.W. ..	46·24 %	—	53·75 %
Currumbah, N.S.W. ..	39·73 %	4·16 %	56·11 %

Although Mr. J. E. Carne has expressed an adverse view, it would appear that the widespread evidence of the presence of natural gas within this basin warrants a most thorough geological investigation, accompanied by practical boring tests, by the Government. If gas were found in quantity, it would be of particular value in a semi-tropical to tropical country like Queensland, and, if a Government monopoly, would afford an unique opportunity for the exploitation and utilisation of this natural product under the most favourable conditions.

Very promising appear the prospects for the establishment of a natural-gas industry of importance in Transylvania, where at Kissarmas very large quantities of gas have been discovered in recent years in the Miocene formation from 19 relatively shallow wells, which showed an initial flow of over 82,000,000 feet per day. Natural gas is there a Government monopoly, and extensive pipe-lines for transportation and distribution of the product were nearing completion before the War.

Attention has also been drawn to the prospects for development of natural gas in quantity both in Rumania and Galicia by Continental engineers and geologists, but no developments of importance have yet taken place.

Russia produces a relatively small amount of natural gas from the Tertiary Surakhani gas-field, and Italy contributed an output of 212,330,000 feet in 1913, the gas occurring also in Tertiary beds.

A comparison between the petroleum and natural-gas industries of the United States is interesting and instructive.

If the value of the petroleum production of the United States in 1914, which exceeded 66 per cent. of that of the world, be compared with that of natural gas sold in that country, it will be seen that the value of the natural-gas production was 44 per cent. of that of petroleum, in spite of the phenomenal output of the new oilfields. On the other hand, the value of the total natural-gas production since 1882, i.e. during the 32 years' life

of the industry, exceeds 37 per cent. of the total petroleum output since 1859, or during 55 years of the petroleum industry.

This in itself is remarkable, in view of the low prices for which natural gas has been sold in the absence of world markets; but equally striking is the gradual manner in which the natural-gas output has become of greater importance than that of petroleum in a number of the great oil-producing States in which the value of the gaseous fuel has been recognized. By 1905, Pennsylvanian oil yielded first place to natural gas; in 1907 West Virginia; in 1910 New York; whilst the Ohio oilfields gave up their lead to natural gas only in 1914.

By 1914 natural gas held the premier position in the following States:—

	Value of Natural Gas.	Value of Crude Petroleum.
West Virginia	$35,515,329	$18,468,540
Pennsylvania	20,401,295	15,573,822
Ohio	14,667,790	13,372,729
Kansas	3,340,025	2,433,074
New York	2,600,352	1,760,868
North and South Dakota ..	27,220	—

In two of the greatest oil-producing States of the world, Oklahoma and California, the natural-gas industry has begun a vigorous career, and especially in Oklahoma may be expected to expand very rapidly.

It will be observed that the petroleum output of West Virginia is less than 52 % of that of natural gas, and that of Pennsylvania is about 76½ %.

At the present time the average value of the natural-gas production per well in the United States exceeds that of oil by almost three times, and where the gas wells are properly taken care of, their life is in general greater than that of oil-wells, the long-lived oil-wells of California possibly excepted.

If it be remembered that the area of the gasfields (about 9,365 sq. miles) is officially estimated to exceed that of the oilfields (about 8,850 sq. miles), that a much greater proportion of the gaseous than of the liquid content of the reservoir rocks is extractable—estimated at about 95 % for gas at against an average of 50 % for oil, and that the practice of conservation is increasing under pressure of new laws, the anticipation appears justified that with the gradually increasing price which is being obtained for the gaseous product, the natural-gas industry will attain a

position equal to that of petroleum in the United States in the not far-distant future.

Further, if the enormous waste which has taken place in the history of the natural-gas industry be taken into consideration, estimated by authorities at between two and three times the total quantity of gas consumed, in the light of the foregoing figures, it may be submitted, even if allowance be made for waste in the petroleum production, that the evidence is strongly in favour of the assumption that the total yield of natural gas has exceeded that of petroleum not only in weight, but also, if natural gas be considered as a liquid, in volume, as well as in value. Thus the comparison of the two industries up to date is in favour of the little-appreciated natural gas in every respect, from the national standpoint. It also throws into relief the appalling nature of the waste, the necessity for sympathetic and wise, but strict, legislation to preserve for the use of the people this most perfect, but most elusive, of all natural fuels, and the great stability of the industry if properly regulated and safeguarded.

As is evident from the preceding considerations, natural gas, where found in quantity, is directly important only to the country in which it occurs, but it is one of the greatest assets and vitalising agents that any country can possess for its social and industrial development. Whilst, unlike other fuels, its nature precludes its transportation, exportation and sale in large quantities abroad (except by land, and then only within a profitable piping limit of about 600 miles), this disability renders it all the more important to the country of its origin, for it must be used there, and, by ameliorating the conditions of life and by furnishing cheap power, renders permanent settlement and the inauguration of local industries quicker and easier of realisation than would otherwise be the case.

It is much to be hoped that those other countries, which are allowing natural gas to be wasted unchecked, or which possess undeveloped natural-gas resources, will study the history of the North American natural-gas industry, and will appreciate the importance and significance as a national asset of this fuel, before enacting laws for the regulation of the development and exploration of the mineral in their own lands.

[A bibliography of Natural Gas would appropriately follow here, but would occupy nearly 30 pages, a space which we cannot spare for it. Its issue as a separate publication is a matter awaiting less strenuous times for consideration. —Ed.]

DISCUSSION.

The President said he did not think the members would be accused of being a Mutual Admiration Society if they agreed that the high standard of excellence of the papers which had been read before the Institution had been fully maintained in the latest addition to their number. It was peculiarly gratifying to him, on the eve of his retirement from the Chair, to have heard such an exceedingly valuable paper, on a subject of the greatest national importance, so admirably presented. He was very glad that the author had devoted so large a part of his paper to the subject of waste, and that he had not scrupled to use somewhat strong language in dealing with that subject. In several of the present and prospective oilfields of the British Empire, the natural-gas industry was either in its infancy or as yet unborn; consequently the opportunity presented itself of taking advantage of the experience gained in the United States and, by the adoption in good time of the necessary measures, preventing the occurrence of what had been very properly described by the author as the appalling waste in the United States of the most valuable of natural fuels. He hoped that the attention of the Authorities who were responsible in matters of the kind dealt with would be drawn to the paper, and, further, that the members of the Institution would bear it in mind when they found themselves, in the course of their work, in a position to inculcate the knowledge that the author had placed before them. He knew Pittsburg in the days prior to the introduction and lavish use of natural gas in the great industries of that city, to which the author had referred, when the atmosphere was so laden with the products of combustion of highly bituminous coal that it was customary and, in fact, necessary, to keep a special suit of clothes for wearing in Pittsburg and nowhere else. He had known Pittsburg in the subsequent period, when the conditions were entirely altered by the too cheap supply of natural gas, which led to its wasteful employment in industries in which it was not, as the author had pointed out, absolutely needed. He confessed that from an æsthetic point of view the change was a very welcome one, but from the standpoint of the advocates of the due and proper conservation of natural resources, the procedure at that time, though it led to the city having a beautifully clear atmosphere, such as it never had before, was nevertheless akin to the action of a reckless spendthrift.

Prof. Cadman said he desired in the first place to endorse what the President had said regarding the excellence of the paper.

The members expected an interesting contribution from the pen of the author, who was a man who had made a special study of the subject of natural gas, and this expectation was more than realised, for a more comprehensive account of the subject had never before been submitted to any technical Society in the country. It was a little difficult to offer remarks upon a subject so fully treated, for it did not lend itself very well to general discussion. All would endorse the author's statements regarding the waste that at present took place upon oilfields in connection with this fuel.

Although it was not quite a parallel subject, he desired to be allowed to refer to a matter which was of vital importance to this country, the question of natural gas associated with coal. It was his privilege some nine or ten years ago to undertake an investigation for a Mines Commission, in which he examined the atmospheres of the mines in this country, the result of which was published in a Blue Book. Some data were contained in his Report which were very pertinent at the present moment in connection with the author's references to natural gas associated with coal seams. There were in this country many mines from which large volumes of methane were being daily poured out into the atmosphere; one mine which he knew gave off the enormous figure of 4,000,000 cubic feet of gas per day. It was of course mixed with air, and the chemical and physical problem of the extraction of that energy still awaited solution. Taking the output of this country as 270,000,000 tons of coal per annum, he estimated that on an average from $1\frac{1}{2}$ to $2\frac{1}{2}$ billion cubic feet of natural gas per annum were poured out from the mines into the atmosphere. It was a subject, therefore, worthy of every consideration. It was a very difficult problem to extract 1 or 2 per cent. of methane from the atmosphere, but nevertheless in some mines it appeared as blowers, and in such cases use was made of it. Some years ago Sir Lindsay Wood investigated the pressures obtained in a coal-mine in the north of England, and, if he remembered rightly, found that pressures existed of 400 or 500 lbs. to the square inch. Some work had also been done on the subject in Westphalia, which proved that coal carried with it considerable quantities of gas. He merely ventured to draw attention to the subject as one that might receive the attention of the Institution. The actual extraction and use of natural gas were topics more or less foreign to the coal miner, but very important and pertinent to the petroleum technologist. There was one point on which he desired to ask the author to amplify his paper, as he thought by so doing it would form a most useful work of reference to those who wished

to study the subject. A bibliography and some reference to the extracts made would prove of great value, because after perusing such a paper one's appetite became whetted. If such an addition was made, it would enhance the value of the author's contribution.

Mr. E. H. Cunningham Craig said that, having had personal acquaintance with a natural-gas field the exploitation of which was due to the author, he had had the opportunity of admiring very much indeed, owing to the coldness of the weather, the gas extracted from that field. He had also had a certain amount of experience of the great gas fields in Western Canada, having seen some of the great wells at Medicine Hat and Bow Island, at the latter of which the largest well was supposed to have produced as much as 29,000,000 cubic feet of gas per day. He had naturally been attracted by the problem of the occurrence of that gas, and its association with liquid petroleum, and the reason why gas was found in one place, and liquid petroleum in another. The author had given a clue to those problems, but he did not think it could be said that they were entirely settled yet. They did know, however, that a very great part of the Cretaceous formation of Western Canada, which was full of gas, remained to be tapped; in fact, there was an enormous area which had not been hitherto tested. It was possible to get sufficient gas to supply an office and a few houses by drilling to a depth of something like 120 feet in some parts of Western Canada, but along the lines of the interesting contour map the author had shown very great gas fields remained to be discovered. Natural gas had played a most prominent part in the development of Western Canada, particularly at Medicine Hat, where several industries, such as brick-making, had been started as a consequence of its use. He also knew that in Calgary the gas had been a very great boon to the domestic consumer. A man who lived there in a frame house, which was little more than what the natives called a "shack," woke in the morning to find that the temperature was 50° below zero, but, as he had natural gas laid on to the furnace in the house, he simply had to reach under the bed, pull a chain which opened the burner a little further, and soon the house was so delightfully warm that he was brave enough to get up. The inhabitants of this country did not realise how much that meant to people who were roughing it under the conditions of life that existed in Western Canada. He had seen some of the demonstrations made with gasol, and they were really most remarkable. He had seen an installation which could be supplied by cylinders, delivered regularly, in which a mutton chop could be kept in cold storage

at one part of the arrangement by the expansion of the gas, and a little further on it could be cooked by the gas. He had seen the gas used with a blowpipe, metals being brazed with it, or holes bored in them. He had had a little of it poured into his hand, and, after waiting from a minute to a minute and a half, while it evaporated, a little drop of frozen moisture had remained. He had not seen it used in a motor car; the great difficulty experienced in that respect, being that it was so difficult to get a small enough aperture to allow the gas to escape from the gasol. A carburettor is of course needless. He believed, however, that there was a future for it in connection with motor cars. If a regular supply could be obtained of the cylinders, it was possible to heat and light a house, cook the food, or keep it in cold storage, and, in fact, do almost anything with it. He thought there was a very great future before the gasol industry if it was properly taken up, especially in oilfields where there was a big flow of "wet gas" from the wells. In that connection he had seen the Bessemer compression plant in use at the famous Dingman well, but it was not so successful as might have been expected. Theoretically something like three gallons per thousand cubic feet should have been produced, but he believed that never more than two gallons had been obtained, and he doubted if that was obtained for very long. But certainly wet gases with a Bessemer compression plant were capable of yielding very good profits to a Company that had a sufficient flow of wet gas at its command. He wished further time was available for fuller discussion of some of the interesting scientific points that the author had raised.

One of the most important points mentioned in the paper was the waste of gas, a subject which had no doubt been taken up very carefully indeed in the United States, and would have to be considered just as carefully in Canada. Conservation of energy (for that was what it really amounted to) must be considered in the Empire very much more carefully than it had ever been before, if the full use of our natural products was to be obtained.

Mr. Hardy Manfield said that, whilst the author had mentioned the presence of natural gas in many countries, he had made no mention of the natural gas that existed in this country at Heathfield in Sussex. At the last meeting of the Institution, when dealing with the question of oil-shales, he (Mr. Manfield) mentioned that the natural gas at Heathfield might possibly have originated in the oil-shales found in the Kimmeridge measures which existed some distance below the surface. He would be glad to have the author's opinion of the origin of this natural gas at Heathfield,

and to hear whether he was aware of any reason why this gas, if properly handled, should not be turned to a profitable account, and be the means of saving the consumption of a considerable amount of coal.

Mr. W. H. Dalton said that as he was acquainted with Heathfield he would like to reply to the questions asked by the previous speaker. There was a very small dome at Heathfield, and the deeper-seated beds rose at high angles of dip within a mile or so distant, so that they had probably lost the greater part of their gas, if they ever had any. There was a small collection in the dome, but he was afraid, as he reported a great many years ago, it would suffice to supply only a few hotels and houses for a short period.

Dr. J. A. Leo Henderson said he had practically nothing to reply to, as all the speakers had been exceedingly kind in commending his purpose in writing the paper. He had visited the district of Heathfield only once, and was therefore not so familiar with its geology as Mr. Dalton, but he had gained the impression that sufficient care had not been taken in casing the wells, and excluding water. He had in his paper referred only in a general way to fields in the Empire which were productive, or which appeared to him to offer possibilities of very large development. Apart from Heathfield, in New Zealand and other portions of the Empire a certain amount of natural gas had been extracted and used for power purposes, but not in very large quantities. The subject was too wide to allow of detailed reference to various fields within the limits of a single paper.

On the motion of **The President**, a very hearty vote of thanks was accorded to Dr. Henderson for his valuable paper, and the meeting terminated.